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GEOPHYSICS

A Journal of General and Applied Geophysics

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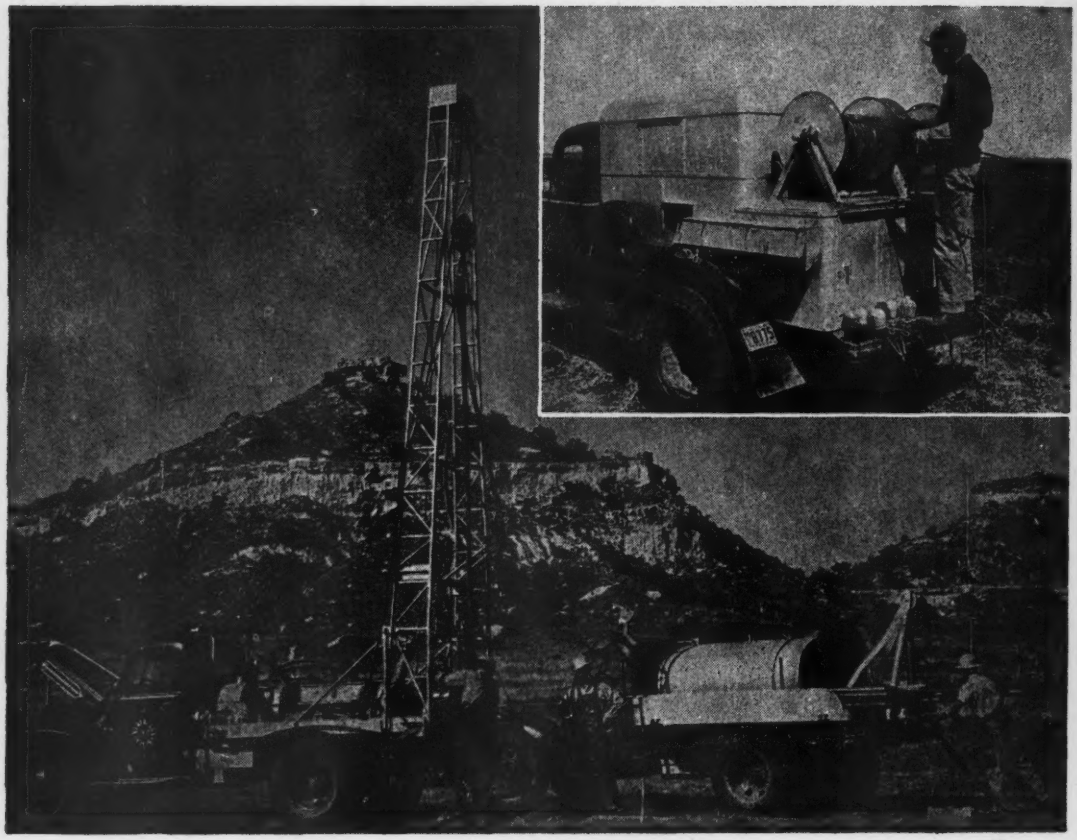

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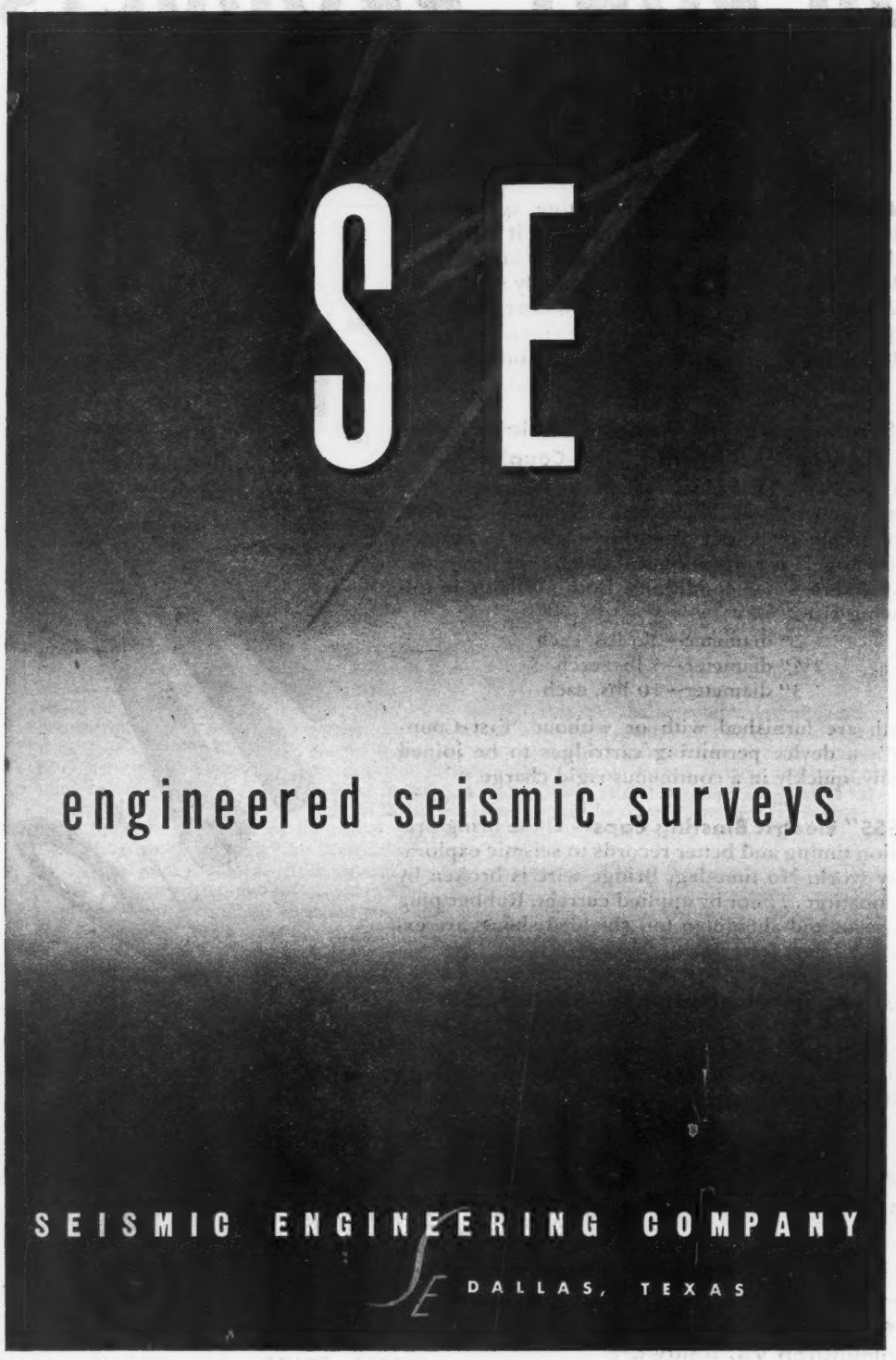
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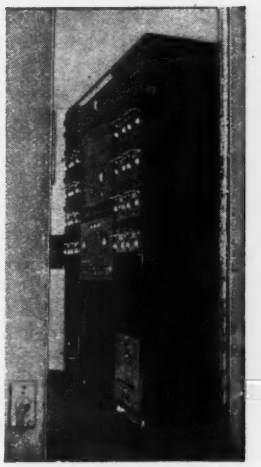

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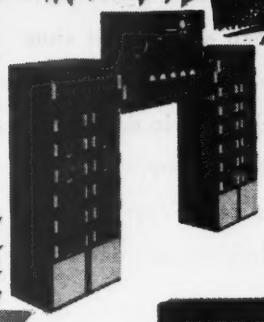

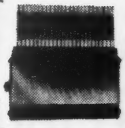

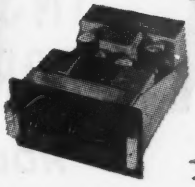

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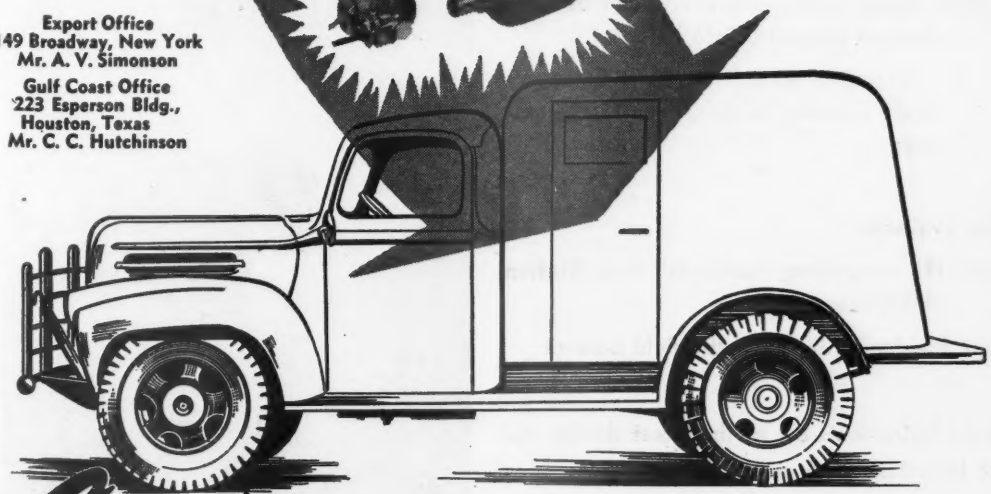

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GEOPHYSICS

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GEOPHYSICAL HISTORY OF EAST LANCE CREEK AND LITTLE BUCK CREEK FIELDS, NIOBRARA COUNTY, WYOMING

B. G. SWAN†

ABSTRACT

A seismograph survey in 1936 by Continental Oil Company eastward from Lance Creek Field, along a projected surface extension of this fold, led to the discovery of East Lance Creek and Little Buck Creek fields. Maps are presented showing the results of this work and the structure as revealed by drilling wells and surface geology at early and later stages of development. Substantial agreement between the structures as mapped by subsurface and by seismograph is noted.

The East Lance Creek and Little Buck Creek oil fields are located about twenty miles northwest of the town of Lusk, Niobrara County, Wyoming. The general geographic location is shown on the map of Fig. 1. Geophysical work over these two fields by Continental Oil Company consists of only one seismograph survey made in 1936.

Lance Creek, East Lance Creek, and Little Buck Creek fields occur on localized structural closures along one major east-west trending structure. The highest part of the fold is at the Lance Creek Field in Twp's 35 & 36 N, R 65 W. (See Fig. 2.) The East Lance Creek Field in sections 28 & 29, T 36 N, R 64 W, and the Little Buck Creek Field in sections 25 & 26, T 36 N, R 64 W are progressively lower in structural position.

Before being explored with the seismograph only one major structure was recognized from available surface and subsurface data. The earliest known published map of this fold is that of E. T. Hancock,

† Geophysicist, Continental Oil Company.

published in *U.S.G.S. Bulletin 716*, 1920, Plate X. Another combination subsurface and surface geological structure map of the area was prepared by H. L. Baldwin for Marland Oil Company in 1924. This map is illustrated in Fig. 2 and shows the extent of development at that time. It was these geological maps that in 1936 led Continental Oil Company to explore with the seismograph the area eastward from

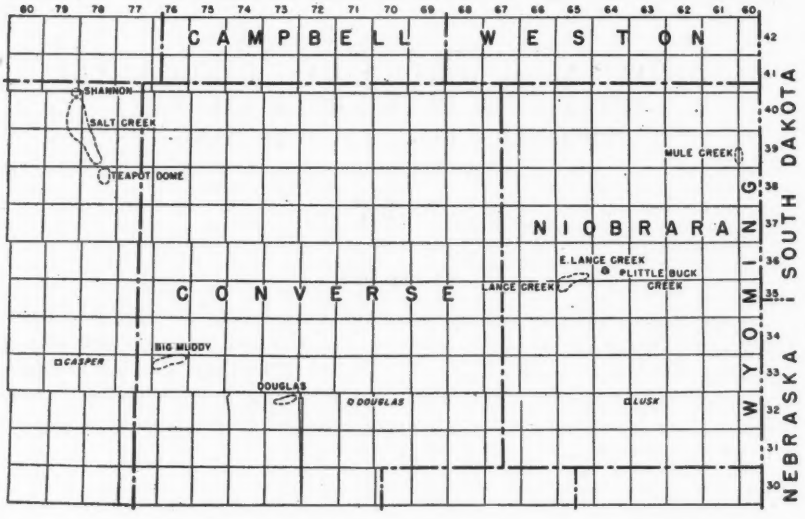


FIG. 1. Map showing location of the East Lance Creek and Little Buck Creek oil fields, Niobrara County, Wyoming.

Lance Creek, in the hope of finding other possible closures along the structural axis.

The seismograph survey was conducted by a Continental crew under Dr. J. A. Culbertson as Party Chief. As a preliminary, two-direction wing spread true dip data were obtained from shotpoints scattered along both flanks of the projected surface axis to determine its position and expression in the deeper beds. Then, a continuous profile line was shot from the east end of Lance Creek Field eastward along the axis, with some branches off to the north and south to outline the structure more definitely. While the records in general were good, correlations were not made at the time. The map in Fig. 3 was derived from averaged dips of a zone several hundred feet thick which

included the Dakota sandstone as an upper limit. The length of the dip arrows represents map spacing of 50 foot contour lines, and the value alongside each arrow is the rate of dip in feet per mile. Judged by present day standards, this was certainly not a very detailed or "finished" shooting job, but it did outline two separate closures east of Lance Creek.

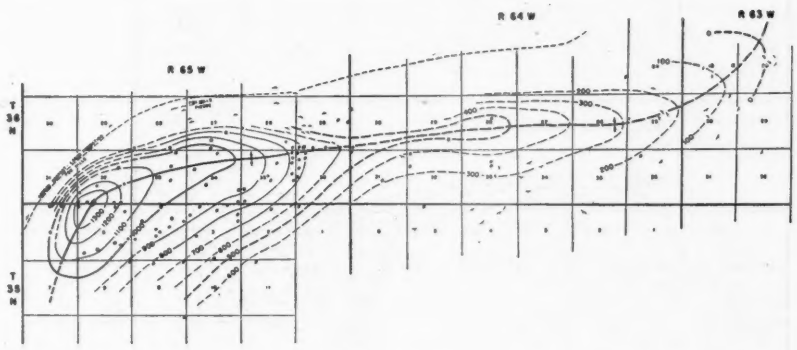


FIG. 2. Combination surface and subsurface map of the major Lance Creek structural feature, made by H. L. Baldwin in 1924 for Marland Oil Company. Eastward elongation of the fold suggests possibility of other closures along the axis. Contour interval 100 feet.

The seismic data indicated that the one well in SW SW NE sec. 28, T 36 N, R 64 W, which had produced oil from the Dakota sand for many years, was a flank well on the structure to be known later as East Lance Creek. With Dakota production on the structure thus already proven, Continental Oil Company and its subsidiary, Buck Creek Oil Company, subsequently acquired acreage and drilled the #1 Leach. The well was located in the SW NE NE sec. 29, T 36 N, R 64 W, drilled into the Madison limestone and stopped at a depth of 6434 feet. No oil was found in any formation but the well was completed December 21, 1937, as a gas well in the Dakota, it being located structurally above the oil column in that formation. Completion of this well opened the East Lance Creek Field, and subsequent development, still in progress, is shown on the subsurface map of Fig. 5.

Early in 1942 a seismic correlation map was made on the Dakota horizon using the 1936 shooting data and available Dakota points in the wells. A relatively new well at this time, the Hintze #1 Wright

in NW SE sec. 30, T 36 N, R 63 W, was of great value in making the correlations, in that it served as an anchor for the east end of the area surveyed. This later interpretation, shown on the map of Fig. 4, gave more prominence to the closure east of East Lance Creek Field, which was later tested by the Continental and Buck Creek oil companies'

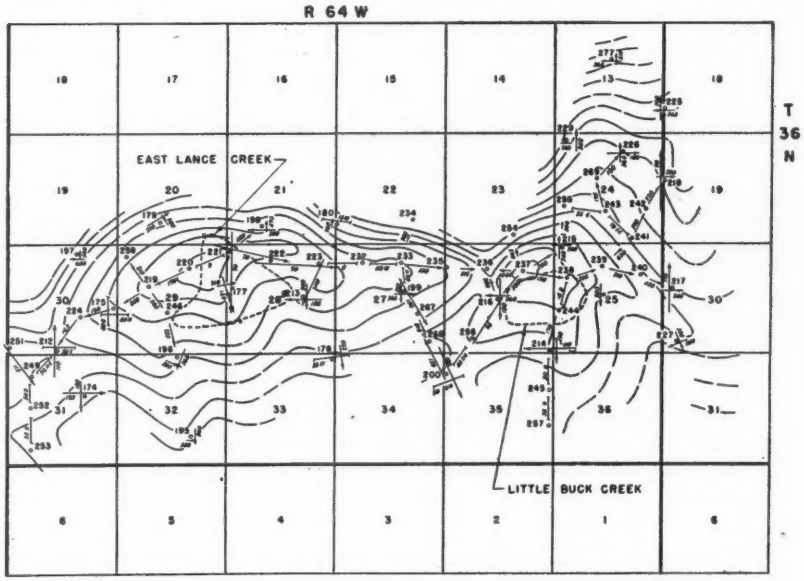


FIG. 3. Reflection seismograph dip map, from averaged dips of a zone including the Dakota sandstone, made by Continental crew in 1936 using scattered wing spread, true dip and continuous profile shooting. Length of dip arrows represents map spacing of 50 foot contour lines, and value alongside arrow is rate of dip in feet per mile. Dotted outlines represent approximate present limits of production. Contour interval 50 feet.

#1 Wright. This well, located in the NW SW NW sec. 25, T 36 N, R 64 W, was completed as an oil well in the Dakota sand on June 18, 1944, to open the Little Buck Creek Field. Development of this pool is still in progress, and is shown on the map of Fig. 5.

A comparison of the maps of Figs. 3 and 4 with the Dakota subsurface map of Fig. 5 shows that there is substantial agreement between the structures as depicted by subsurface and by seismograph data.

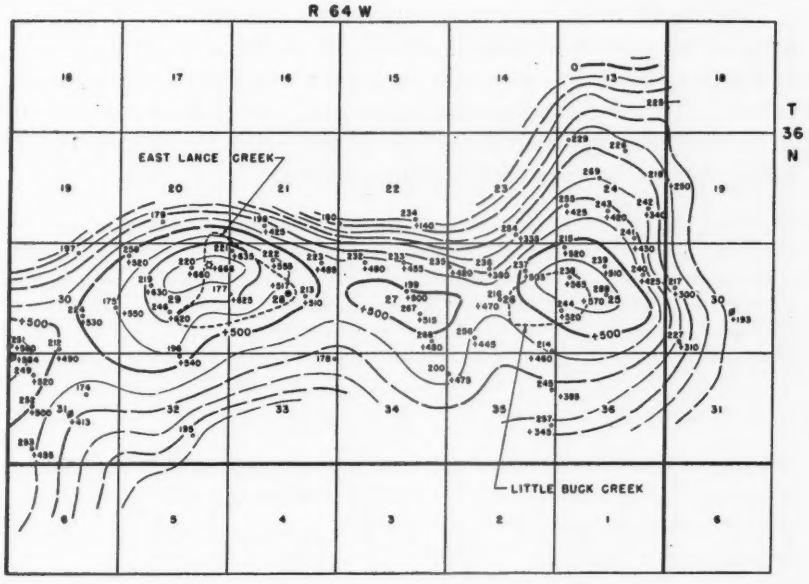


FIG. 4. Reflection Seismograph Correlation Map on the Dakota sandstone, made in 1942 in a re-interpretation of the 1936 shooting data. Compare with Fig. 3 and note increased prominence of Little Buck Creek structure. Contour interval 50 feet.

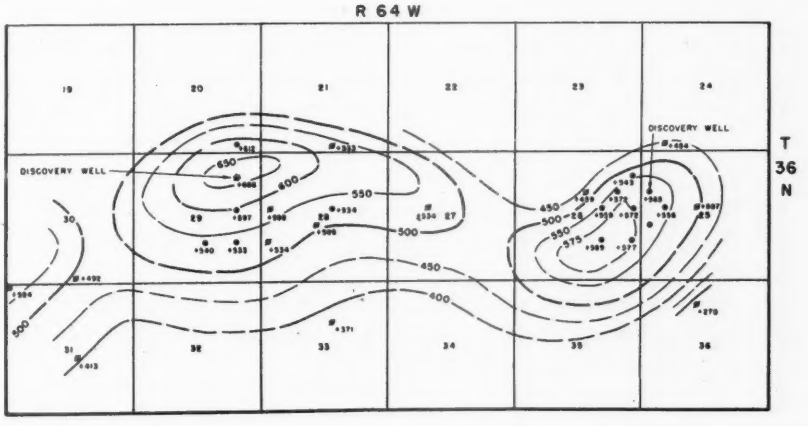


FIG. 5. Map showing Dakota subsurface structure as defined by development to date at East Lance Creek and Little Buck Creek. Contour interval 50 feet.

The writer wishes to express his thanks to Continental Oil Company for permission to publish this paper; to Mr. A. E. Brainerd, Division Geologist for Continental at Denver, Colorado, for surface and subsurface maps and other information of an historical nature; to Dr. L. F. Athy for valuable assistance in preparing the paper; and to Ralph Adams for preparing the illustrations.

GEOPHYSICAL HISTORY OF THE GUTHRIE FIELD, LOGAN COUNTY, OKLAHOMA

B. G. SWAN† AND W. B. BOYD‡

ABSTRACT

The geophysical history of the Guthrie Oil Field, as presented in this paper, consists of a reflection seismograph survey in early 1938; a re-interpretation of these data in 1941; and a detailed reflection seismograph survey in 1941, after the discovery of oil, to outline dimensions of the structure more definitely. Early concern over the fact that Viola reflection times failed to show east closure on the structure was later dispelled when drilling developments showed that closure actually was not present on horizons above the Second Wilcox sand.

The Guthrie Oil Field is about eight miles northeast of Guthrie, Oklahoma, in Logan County. The general location with respect to towns and other oil fields is shown in Fig. 1. The geophysical history of this field is of interest chiefly because the structure as mapped by the seismograph was only a flattening on a westward-plunging nose, with no east closure at Viola limestone depths.

A Continental Oil Company crew, under W. C. Clark as Party Chief, covered the area of the field in the early part of 1938 as part of a general seismograph survey centering about the town of Guthrie. The continuous profile method of shooting was used, with holes spaced about 1800 feet apart. Correlations were carried on several horizons, and all reflection times corrected for elevation changes by use of a reference datum of 1000 feet above sea level. Up-hole times were used for weathering corrections.

The maps of Figs. 2 and 3 show the results of this survey on the Mississippi limestone* and Pawhuska limestone horizons, respectively. The band of steep north dip along the north parts of sections 8, 7 and 12, on the Mississippi (?) map, is a definite indication of structural reversal. The elongate east-west nose confirmed the suspected westward extension of a subsurface trend which was well de-

† Geophysicist, Continental Oil Company.

‡ District Geologist, Continental Oil Company.

* Later, definite velocity information proved that the reflection event on which this "Mississippi" map was made actually represented Viola depth. The map is presented here without correction, however, since it was the only Pre-Pennsylvanian map in our files at the time the first well was started on the structure.

fined east of Langston at that time. There was, however, no east-west closure shown by the contours on this map. In the party chief's final report it was said that,—"East dip was not established, and the relation of this feature to the Langstone structure is not known. It may be a west-plunging nose off from it but it is more likely a separate feature with at least some closure." Under recommendations,

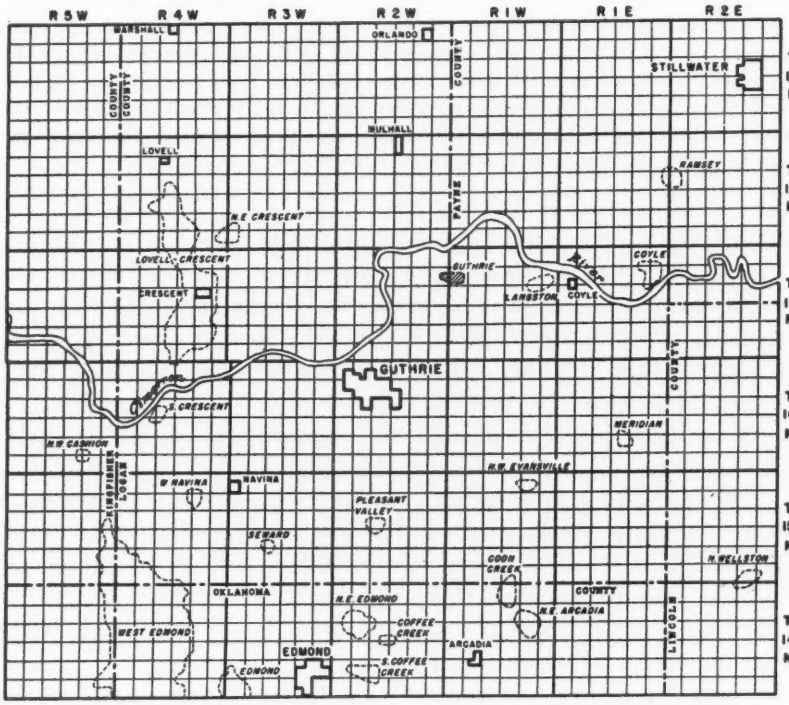


FIG. 1. Map showing location of the Guthrie Oil Field, Logan County, Oklahoma.

the statement was made that—"Additional acreage should be acquired if possible on—[this structure]."

At the time of the first survey, Continental owned one lease on the structure, and subsequently acquired one or two outlying pieces.

In the latter part of 1940 Continental was approached by Mr. E. W. Hamilton of Tulsa with a request for financial assistance in drilling a well in C NW SE $\frac{1}{4}$ of section 7. On the basis of the 1938 seismograph work, Continental purchased an 80-acre lease on the E $\frac{1}{2}$

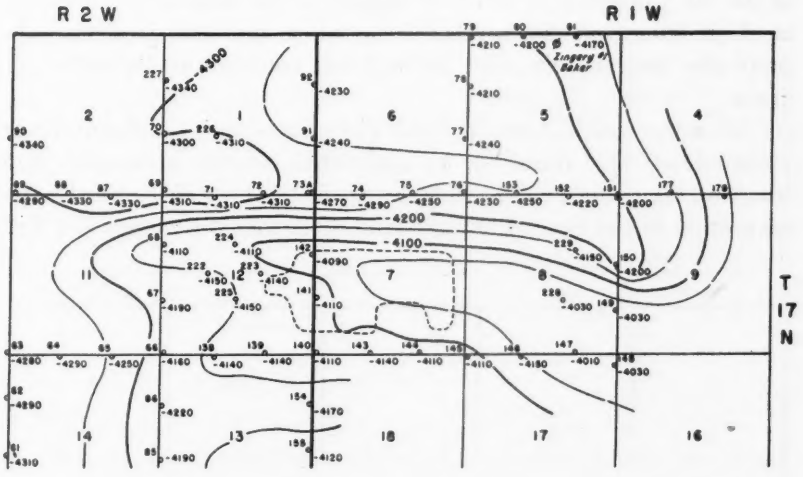


FIG. 2. Map showing results of first reflection seismograph survey by Continental in 1938. "Mississippi" datum values are as originally interpreted and were later proven to be representative of Viola structure. Contour interval is 50 feet.

(Dotted line on this and other figures shows approximate limits of production.)

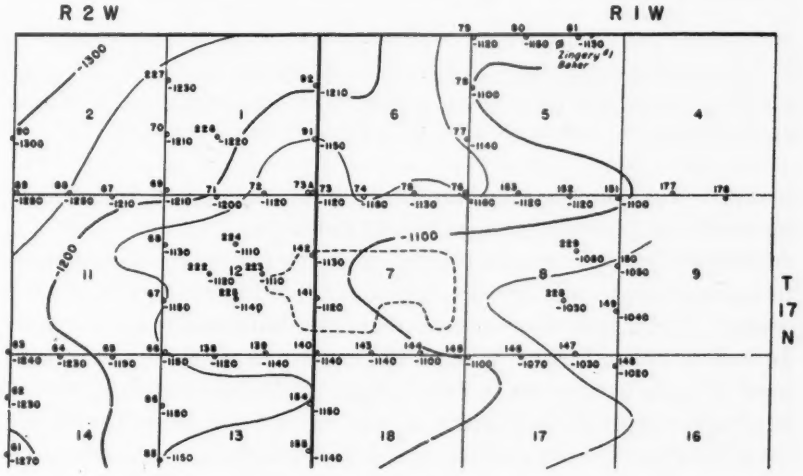


FIG. 3. Map showing results of first reflection seismograph survey by Continental in 1938 on the Pawhuska limestone horizon. Contour interval is 50 feet.

of the SW ¼ of sec. 7, 17N–1W as support to the drilling of the Sunray et al. #1 Donoghue. Sunray Oil Corporation and Fain Drilling Company also lent support, and the well was spudded on December 31, 1940.

After the well had reached the Viola limestone, Continental purchased from Mr. Hamilton an additional interest in several more leases on the structure. The well was dry in the First Wilcox but found saturation in the Second Wilcox sand. The well was completed Feb-

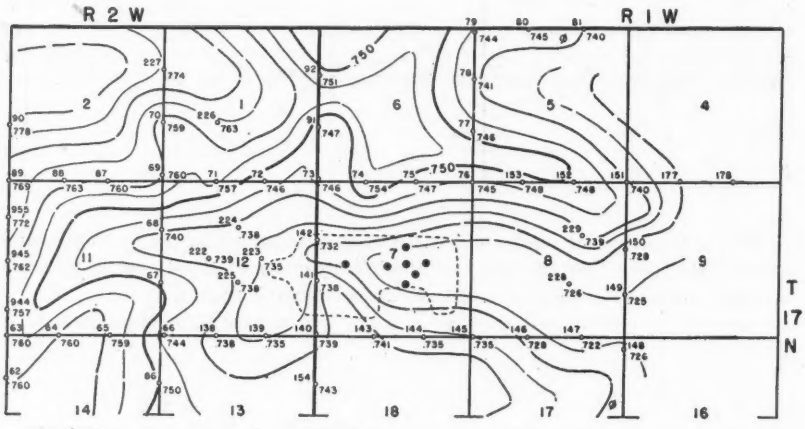


FIG. 4. Reflection time datum map of the Avant-Dewey horizon, showing results of a re-interpretation of the 1938 seismic data. Times were adjusted to an elevation reference datum of 1000 feet above sea level. Contour interval .005 secs.

ruary 16, 1941, flowing 611 barrels in 6 hours through 2½-inch tubing for an official potential of 2444 barrels per day.

The field was developed rapidly, with the producing area confined to approximately 320 acres by 29 producers and 4 dry holes in the field proper. Production was developed in the Bartlesville sand horizon as well as in the Second Wilcox, the two zones together producing a total of 3,160,018 barrels to July 1, 1946. At the present date the field is almost depleted, and many of the wells have been abandoned.

Following discovery of oil in the #1 Donoghue, a restudy of the 1938 seismic data was made in connection with a new seismograph survey extending the trend westward. This survey was by a Continental crew under Mr. E. J. Handley. No new work was added over the field proper, but the results of a re-interpretation of the 1938 data are

shown in Figs. 4 and 5. Fig. 4 shows the data, in reflection time, on the Avant-Dewey horizon corrected to an elevation reference datum of 1000 feet above sea level, while Viola data are similarly shown in Fig. 5. It should be noted that these two maps are contoured on .005 second interval, which is equal to only about one-half the contour interval of the maps in Figs. 2 and 3. This was done to emphasize minor undulations in the contours, but it is seen that otherwise the

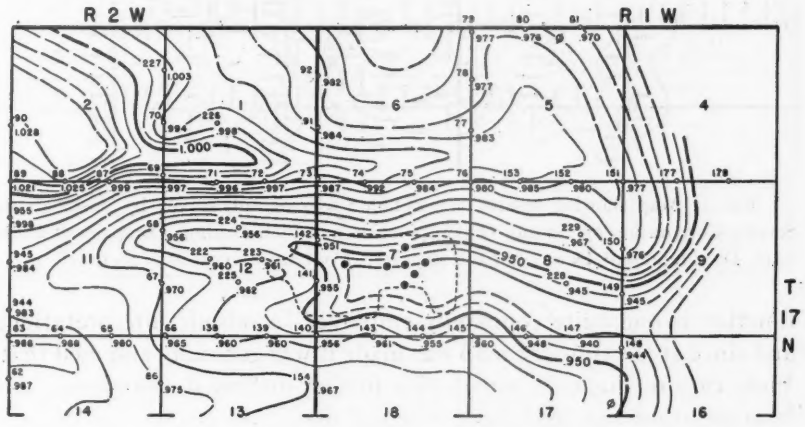


FIG. 5. Reflection time datum map of the Viola horizon, showing results of a re-interpretation of the 1938 seismic data. Times were adjusted to an elevation reference datum of 1000 feet above sea level. Contour interval is .005 secs.

new interpretations are very similar to the old. Though correlations were considered definite, still no east closure was found.

Also in the early history of the field, about March, 1941, a detailed seismograph survey was made by a Seismograph Service Corporation crew, under Mr. G. A. Grimm as Party Chief. This survey was made for the joint account of Sunray Oil Corporation and Fain Drilling Company, et al. The resulting structure on the Dewey horizon is shown in Fig. 6, with the depths computed by use of a constant velocity. Fig. 7 shows Viola correlations in reflection time, corrected to an elevation reference datum of 900 feet above sea level. Fig. 8 is an interpretation in which these Viola times were converted to sea level datum in feet by use of a varying velocity function which seems to result in more east closure than is shown on the reflection times themselves. The principle involved in the use of this velocity

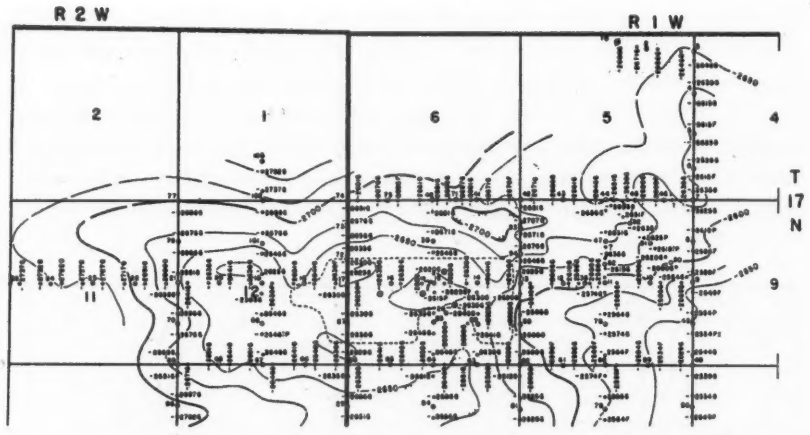


FIG. 6. Map showing results of a detailed seismograph survey by Seismograph Service Corporation for Sunray Oil Corporation and Fain Drilling Company et al. in 1941. Data represent Dewey horizon structure. Contour interval is 25 feet.

function is one quite commonly employed in seismic interpretation, and since at the time the map was made it was generally assumed that Viola closure would be found with further drilling development, the interpretation was considered a logical one.

As shown in the subsurface maps of Figs. 9, 10 and 11, closure did

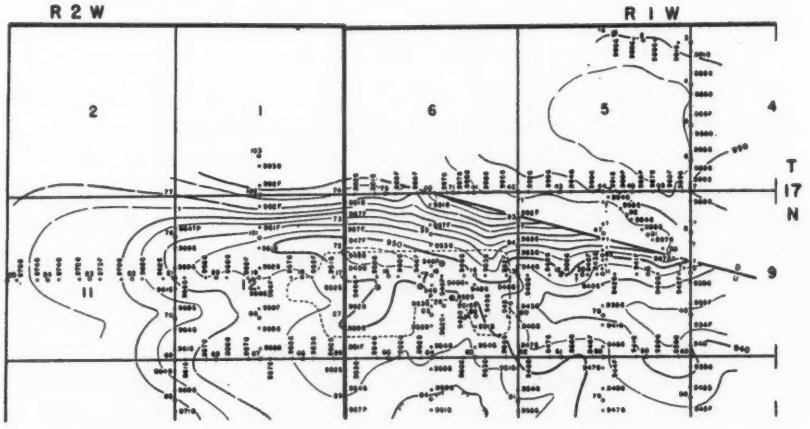


FIG. 7. Reflection time datum map of the Viola horizon showing results of a 1941 detailed survey by Seismograph Service Corporation for Sunray Oil Corporation and Fain Drilling Company et al. Times were adjusted to an elevation reference datum of 900 feet above sea level. Contour interval is .005 secs.

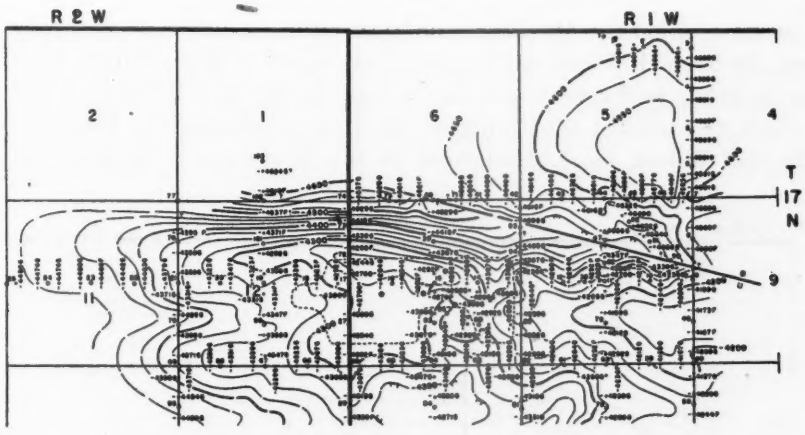


FIG. 8. Map showing Viola time data of Fig. 7 converted to sub-sea data in feet by use of a variable velocity function. Contour interval is 25 feet.

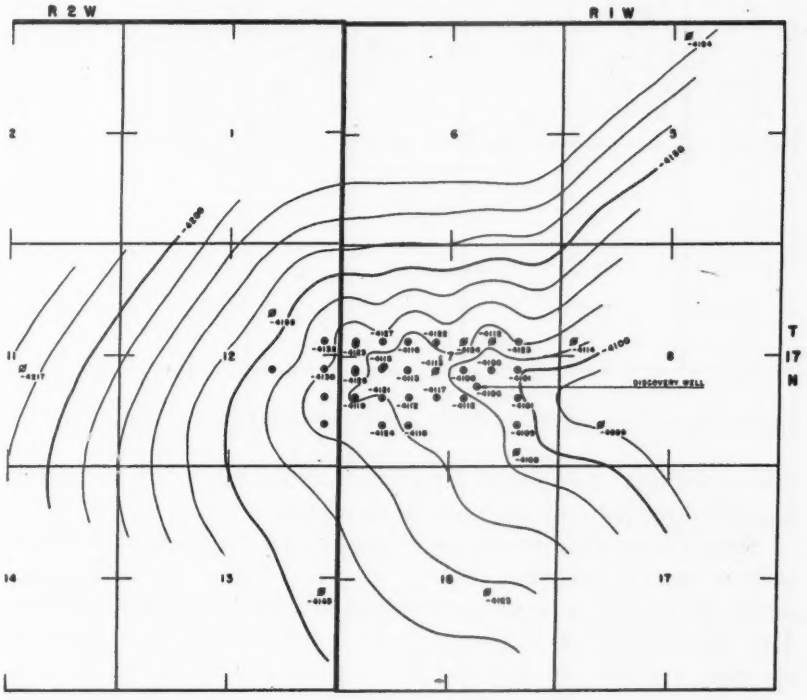


FIG. 9. Top of Mississippi limestone subsurface structure map. Contour interval is 10 feet.

not develop on the Mississippi or Viola horizons, but is present only on the Second Wilcox sand. A detailed study of drill cuttings from wells in the field reveals that east closure on the Second Wilcox is the result of eastward thickening of the section between the First and Second Wilcox sands. Variations in this interval are common but

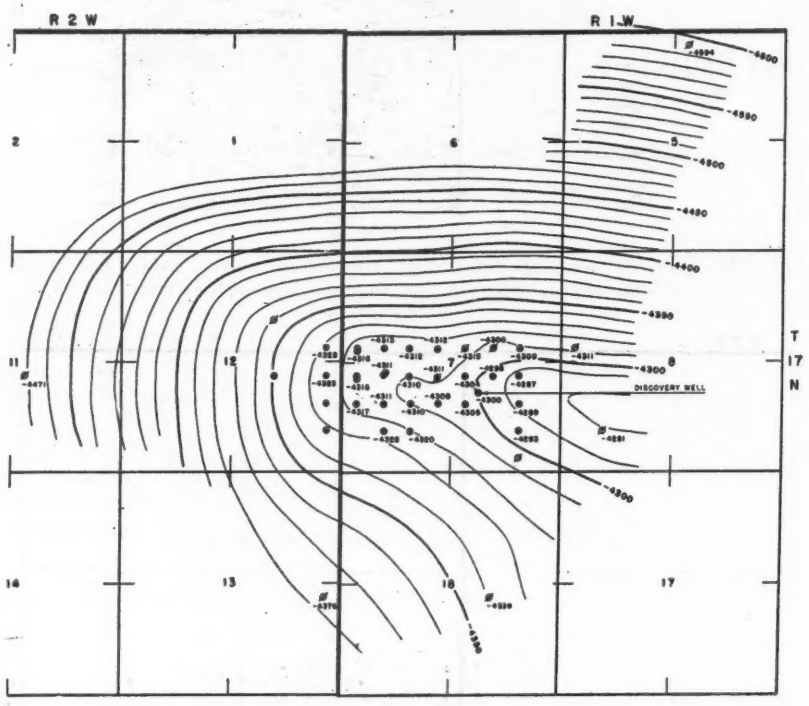


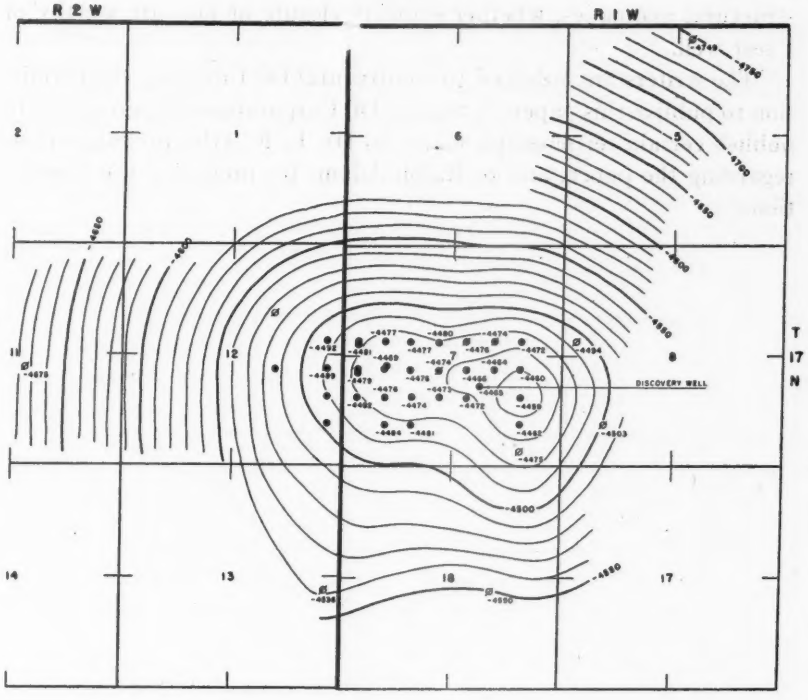
FIG. 10. Top of Viola limestone subsurface structure map. Contour interval is 10 feet.

this is the first example, as far as the writers know, where oil was trapped principally because of this change in interval.

Since closure developed only on the Second Wilcox sand, it seems evident that seismic data at this level and below should be quite significant on this structure and others of a similar geologic history. Although the authors of this paper have not had the opportunity to examine critically the observed data on the detailed survey by Seismograph Service Corporation, it is extremely doubtful that any consistent, authentic reflections were present below the Viola. Conti-

nental's records did not reveal such data, and, it is believed, the experience of others has been pretty generally the same. Occasional Arbuckle reflections are obtained in the central Oklahoma area, but as a general rule they are not consistent enough for good mapping.

Another interesting item in the geophysical history of this field



on the southwest flank and one near the crest, drilling had progressed eastward far enough to show that actual Viola closure was not present, or if so, was of a very limited amount. The program was thus left with little to be gained, so was dropped.

If there is anything of value to be gained from a review of the geophysical history of the Guthrie Field, it is that definite seismic structural anomalies, whether showing closure or not, are worthy of a test well.

The writers are indetbed to Continental Oil Company for permission to publish this paper; to Sunray Oil Corporation for permission to publish certain seismograph maps; to Dr. L. F. Athy for suggestions regarding the paper; and to Ralph Adams for preparing the illustrations.

GEOPHYSICAL HISTORY OF THE WASCO OIL FIELD, KERN COUNTY, CALIFORNIA

E. L. ERICKSON*

August 1946

ABSTRACT

The reflection seismograph surveys which led to the discovery of Wasco oil field were started in 1934. Some additional work was done to outline the structure in 1935. Subsequent to discovery in 1938 a detailed reflection seismograph survey was made for the purposes of aiding development and securing type seismograph data.

The Wasco oil field is located in Kern County, California, four miles west of the town of Wasco. The location of this field with respect to adjacent oil and gas fields is shown by Fig. 1.

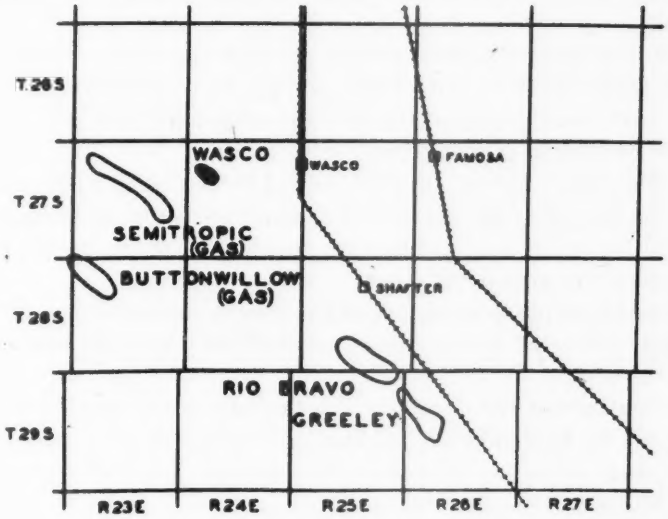


FIG. 1. Index map showing location of Wasco oil field.

The first well drilled in the field was Continental well No. "K.C.L." A-1, located in Sec. 8, T. 27 S., R. 24 E. This well was spudded November 7, 1936 for the purpose of testing upper Miocene formations which

* Continental Oil Co., Los Angeles, California.

had just previously been proved productive in the Ten Section and Greeley oil fields. This well was bottomed at 9591 feet because of mechanical difficulties and was completed on April 26, 1937 as a poor producer from a chert and shale horizon which is equivalent to the upper part of the Stevens-Greeley sand zone which is productive in other fields to the south.

Discovery of the field came on April 11, 1938 with completion of Continental Oil Company well No. "K.C.L." A-2. At the time of its completion this well was the deepest ever drilled, having been bottomed in Eocene formations at 15,004 feet, and was also producing crude oil from the greatest depth then developed. Initial production of 3385 barrels of 37° gravity oil per day came from a lower Miocene sand body 35 feet thick at a depth of 13,095 feet. This sand body was designated the A-2 sand, since it lies slightly higher stratigraphically than the Rio Bravo-Vedder sand which is productive in the nearby Rio Bravo field. It is the only commercially productive sand found in the field.

The field was fully developed by January 1941 with 12 wells producing from the A-2 sand. Three non-productive holes drilled into the A-2 sand on the edge of the field and edge conditions in some productive wells help delineate productive limits.

In Fig. 2 are shown all wells drilled in the field, with contours drawn on the top of the A-2 sand. The structure is that of an elongated dome of low relief with productive closure of approximately 75 feet. The productive area is 385 acres.

The early geophysical history of the area is similar to that of other oil fields discovered in south San Joaquin Valley by reflection seismograph surveys.[1]

A Continental Oil Company seismograph party started work in California in September 1934. During October of that year a long reconnaissance line was run from Buttonwillow gas field across Semitropic Ridge and northeast as far as Sec. 4, T. 27 S., R. 24 E. A continuous profiling method was used in shooting this line, with shot holes spaced about 2000 feet apart. Record quality was excellent, and velocity information was acquired by ΔT analyses of the records. The depth section obtained from the shooting of this line showed no lower Pliocene or Miocene reversal at Buttonwillow and Semitropic; however, a

[1] Henry Salvatori, "Early Reflection Seismograph Exploration in California," GEOPHYSICS, Vol. X, No. 1 (Jan. 1945) pp. 17–33.

deep reversal was found near the southeast corner of Sec. 8, T. 27 S., R. 24 E. These data were the first obtained by Continental at what is now Wasco field.

Additional work was done by Continental in the Wasco area in the spring of 1935. This consisted of several short continuous profile

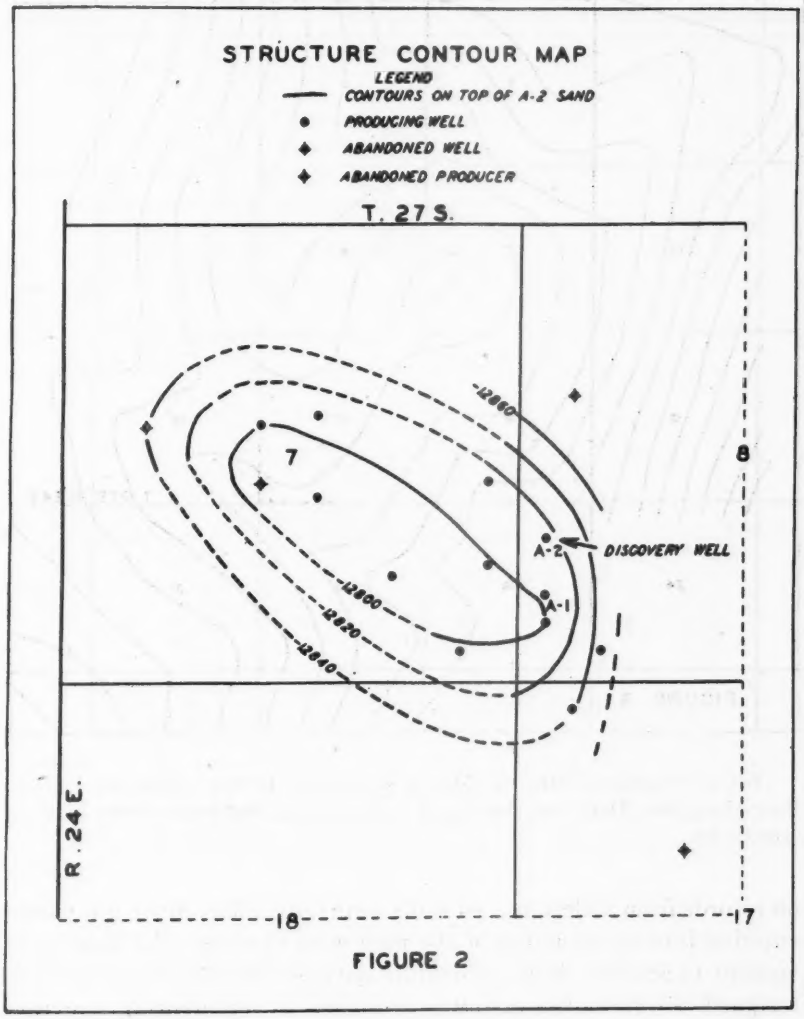


FIG. 2. Subsurface Structure Map of Wasco oil field. Contours on top of A-2 sand. Contour Interval = 20 feet.

lines and a scattering at one mile intervals of isolated shot points from which shots in two directions yielded records suitable for true dip computations. The shot points used, and the interpreted results of this work are shown in Fig. 3. Definite correlations of reflections

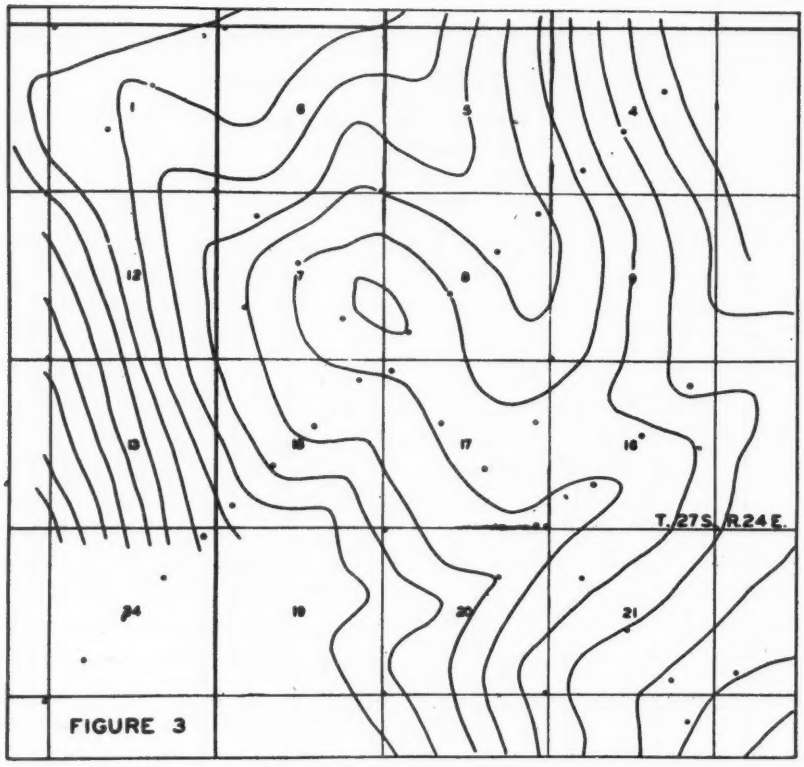


FIG. 3. Seismograph Structure Map of Wasco area. Datum −9500 feet. Contour Interval=50 feet. Data from shooting of years 1934–35. Shot points shown by small open circles.

on records from widely spaced shots were impossible. Since dip values entering into construction of the map were avarages of a zone from 7000 to 12,000 feet deep, no definite datum values for contours were assigned. However the map was presented as representing structure at approximately −9500 feet.

The seismograph work described above was the basis for selection

of the locations of Continental wells Nos. "K.C.L." A-1 and A-2 which resulted in discovery of the field.

In the summer of 1938 it was decided to make a detailed reflection survey of the Wasco area for the purposes of aiding development, evaluating outlying acreage held by the Company, and incidentally

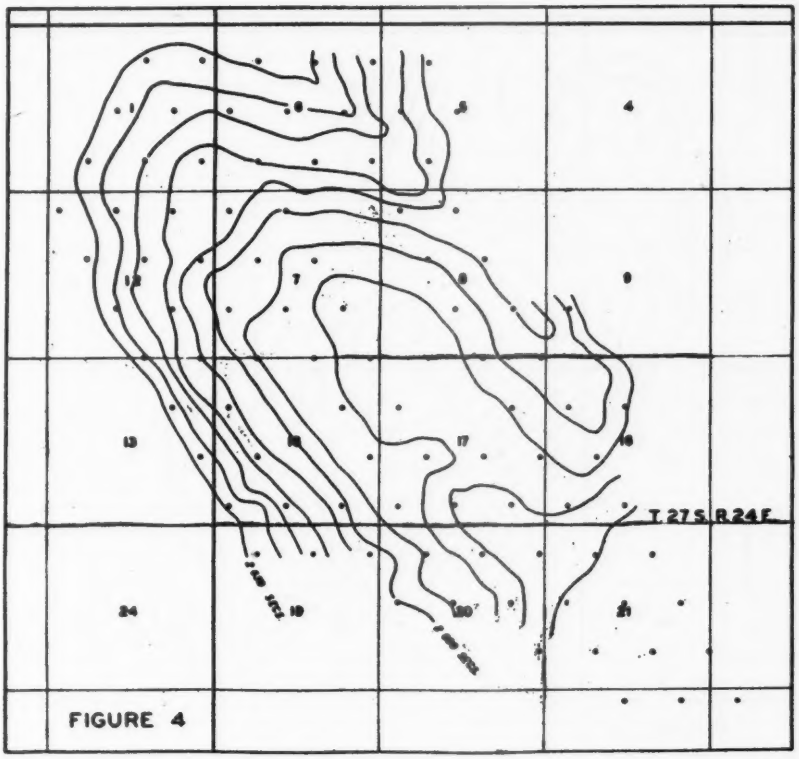


FIG. 4. Seismograph Time Datum Map on Greeley Horizon. Contour Interval=.010 sec=40 feet. Data from detail shooting 1938. Shot points shown by small open circles.

to map as accurately as possible by seismograph a very deep, small, closed structure which could be used as a type example. A velocity survey made in Continental well No. "K.C.L." A-2 furnished accurate velocity control.

A novel scheme of shooting this project was adopted. Lines of shot points were laid out in three directions at intervals of 1800 feet

such that each shot point lay at the apex of an equilateral triangle with 1800 foot sides. The area was completely covered by this network of triangles except where drilling wells interfered. Seismograph spreads 1800 feet long with end points falling at shot point locations were used. Records were taken by shooting the hole at the opposite angle

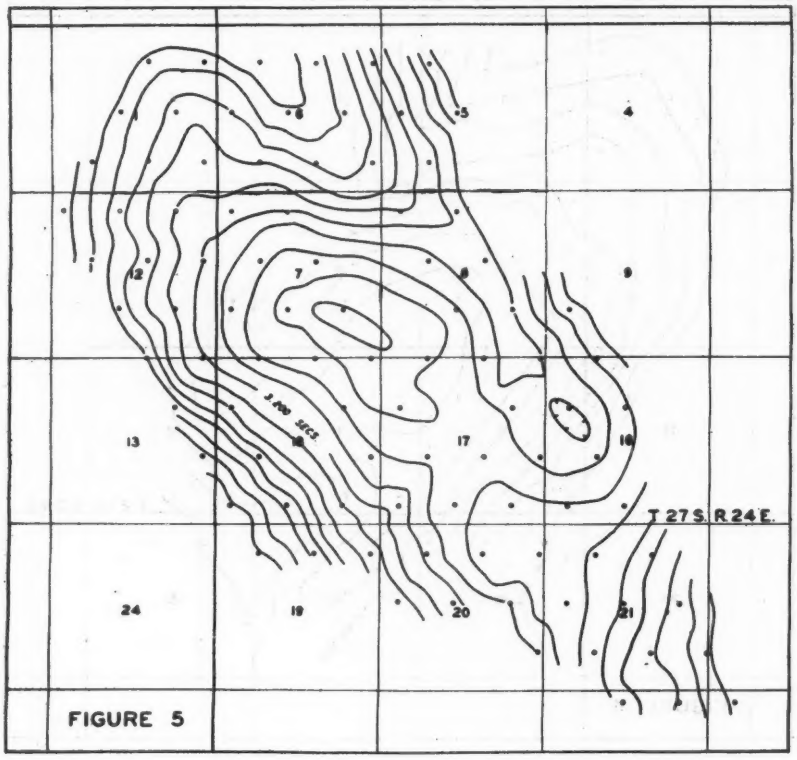


FIG. 5. Seismograph Time Datum Map on Rio Bravo Sand Horizon. Contour Interval=.010 sec=42 feet. Shot points shown by small open circles.

of the triangle to the side occupied by the surface spread. Thus many shot holes were used for as many as six different surface spreads. Uphole weathering data were available for the ends of each spread, and all spreads were offset an equal distance of 1560 feet at right angles from center points of spreads to the shot hole. This system enabled continuous mechanical correlation of reflections and the com-

putation of dip components and true dips. The only complication in the method was the necessity of tracing reflection arrivals across individual records. However, great care was exercised in using a uniform optimum recording technique so that even this hazard was negligible.

The results of the detailed shooting were considered to be the absolute maximum in excellence and density of coverage which could be obtained over this or any similar area. Figures 4 and 5 show two representative maps secured from the work.

Fig. 4 shows a time datum map on an horizon at a depth equivalent to the Greeley producing zone. This horizon does not exhibit any closure, though in general it is comformable with deeper horizons.

Fig. 5 shows a time datum map on an horizon at the top of the Rio Bravo (A-2) sand. The areal extent, position and amount of closure indicated by this map agree quite closely with the subsurface structure map of Fig. 2.

ACKNOWLEDGMENTS

All of these data have been released for publication by Continental Oil Company. The writer has served only to compile the data which resulted from the accumulated efforts of many Continental employees, and wishes to acknowledge the aid given him by Mr. R. M. Barnes, Chief Geologist, California, in the preparation of this paper.

GEOPHYSICAL HISTORY OF THE VILLE PLATTE OIL FIELD, EVANGELINE PARISH, LOUISIANA

PAUL R. WARREN*

ABSTRACT

The brief pre-discovery geophysical activity by Continental Oil Company in the area of the Ville Platte Field consumed twenty-five working days and consisted of a reflection seismograph survey employing symmetrical setups far removed from the shotpoints. After discovery a gravity meter survey revealed a gravity minimum almost coinciding with the seismograph structure and the productive area.

The Ville Platte oil field is located, as shown in Fig. 1, in the East

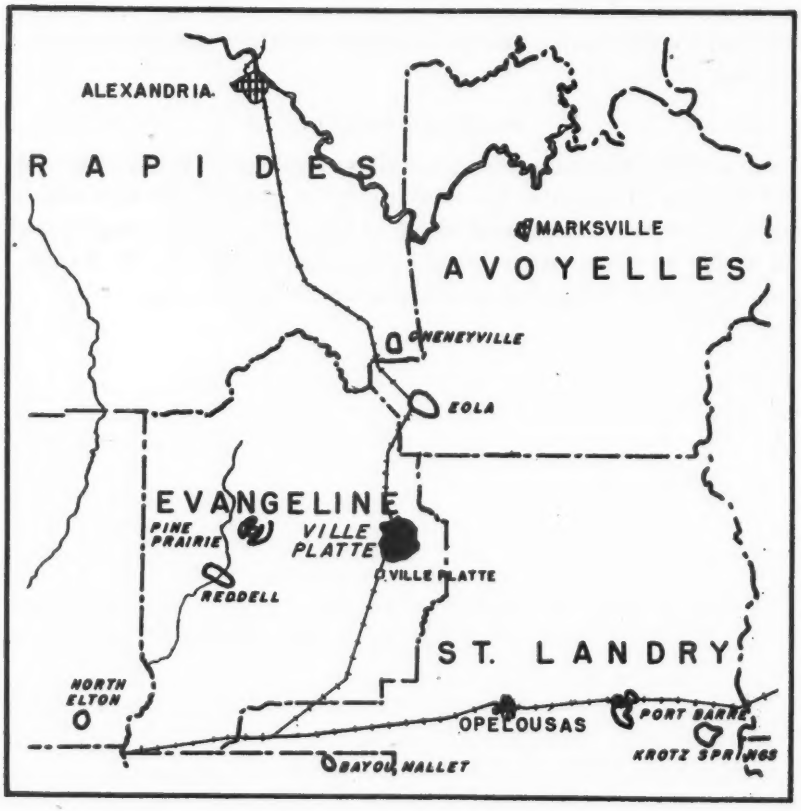


FIG. 1. Map of portion of Central Louisiana showing location of Ville Platte Field.

* Continental Oil Co., Lafayette, La.

central part of Evangeline Paris, Louisiana, a few miles Northeast of the Town of Ville Platte. The first interest in the area was aroused sometime prior to 1930 by surface indications including a difference in soil and vegetation, gas blows, paraffin dirt, and some evidence of a

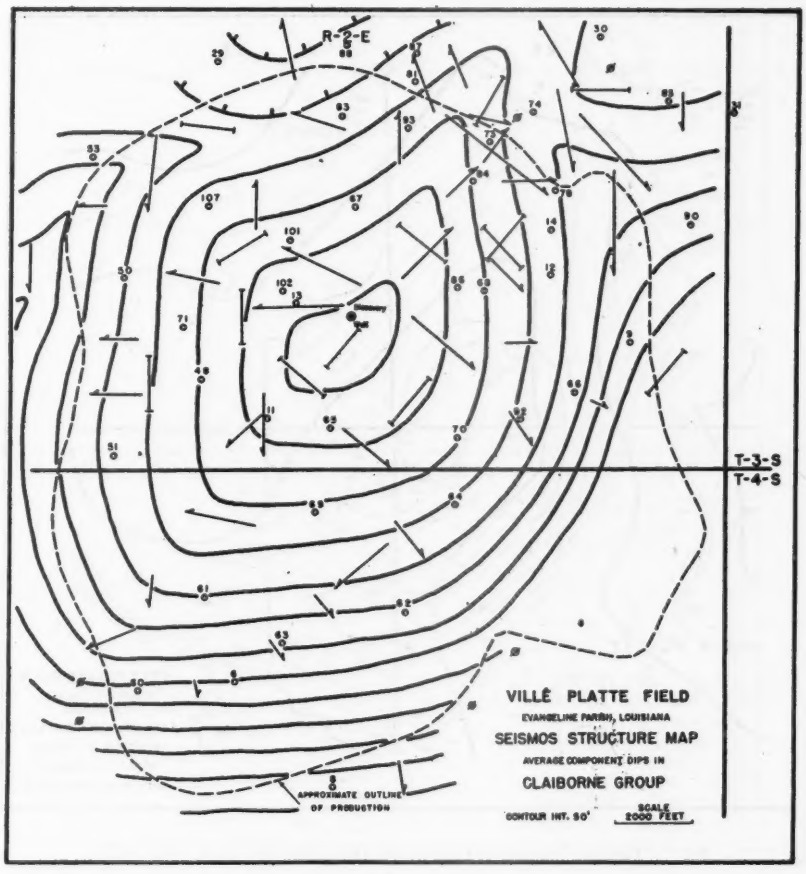


FIG. 2. Seismos structure map by Continental Oil Company crew, 1936.

surface fault. It was first leased in 1933 and during the next three years four shallow dry holes were drilled in the southwest part of what later became the productive area. The deepest of the four reached a depth of approximately 3200 feet. After these failures, interest in the prospect was kept alive by the possibility of deep production.

In 1936, Continental Oil Company acquired a shooting option and

worked the area the same year with reflection seismograph. The shooting was done by a Continental Oil Company crew under the supervision of Dr. J. A. Culbertson. Approximately fifty shotpoints were used and dip components were computed from offset symmetrical

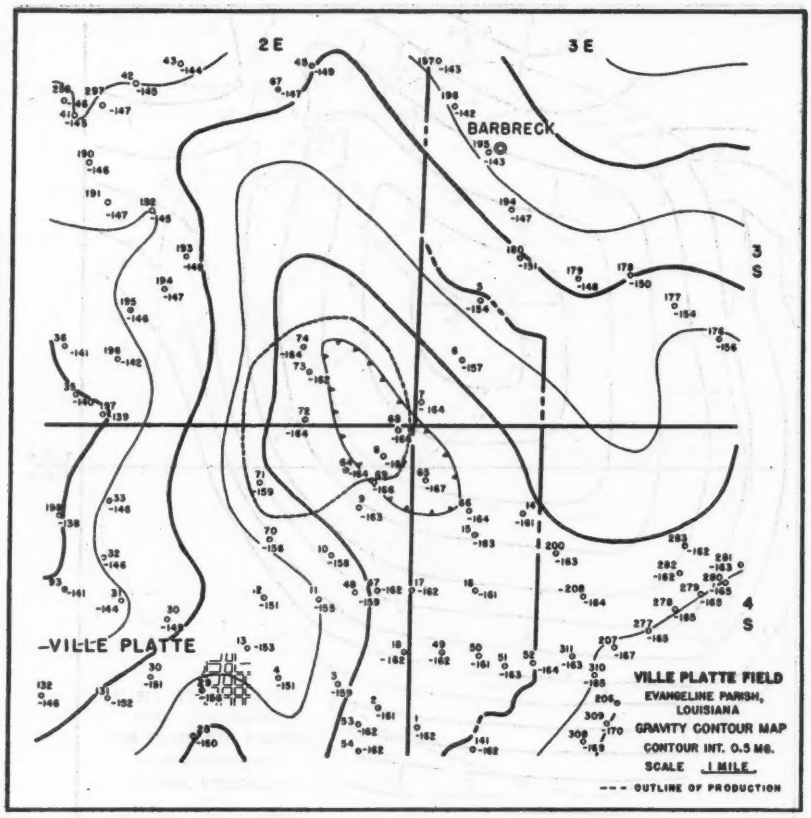


FIG. 3. Gravity map by Continental Oil Company crew, 1938, after discovery of the field.

spreads. The dips are shown in Fig. 2. They were obtained by averaging the values of dips computed on all usable reflections within a depth zone of 7000 to 10,000 feet, approximately. This is roughly the zone occupied by the Claiborne Group. The difficult terrain discouraged close detail but enough scattered dips were obtained to establish a promising closed structure and to locate the top. That this

method of shooting, which largely ignores the hazards of faulting, was a fortunate choice can be seen by a glance at Fig. 4. The resulting contours fit closely the outline of the productive area but show only

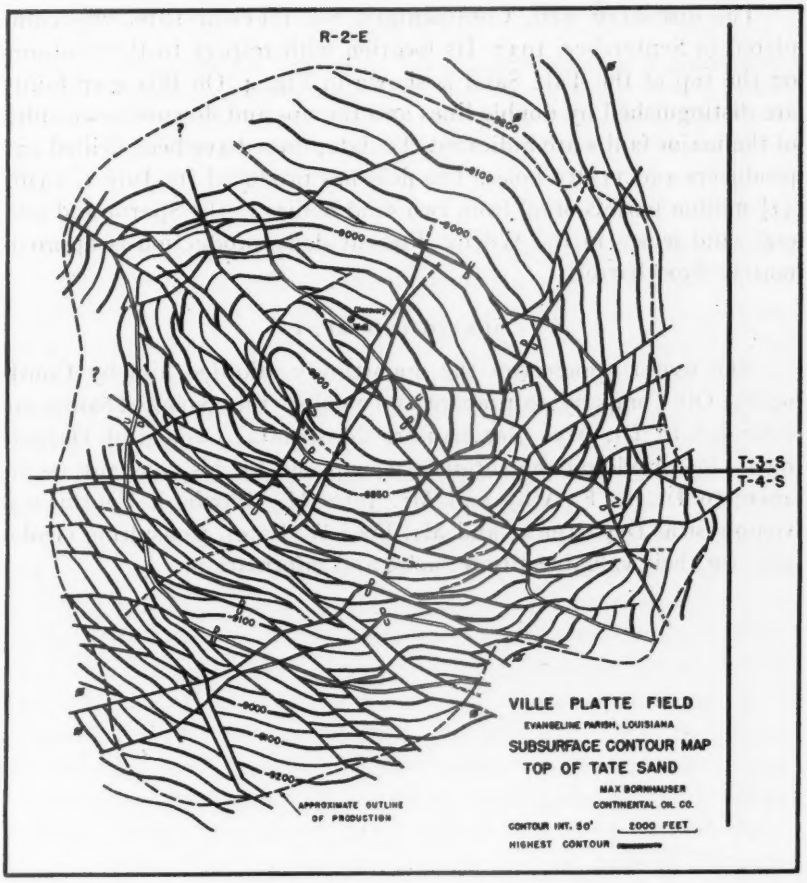


FIG. 4. Subsurface map on one of the producing sands in the Sparta.

half of the closure existing on the producing sands. The location of the discovery well is shown near the center of the closed contours.

In 1938, a gravity survey was made of the field as part of a regional gravity program. The work was done by a Continental Oil Company crew with Cecil K. Jordan as Party Chief. The instrument used was a Mott-Smith Model A Gravity Meter. Fig. 3 shows the

locations and gravity values of the stations read and the pronounced minimum centering near the center of production. The gravity values are in units equivalent to 0.1 milligal and are referred to U.S.C. & G.S. pendulum readings.

The discovery well, Continental's No. 1 Feloni Tate, was completed in September, 1937. Its location with respect to the contours on the top of the Tate Sand is shown in Fig. 4. On this map faults are distinguished by double lines and the up- and down-thrown sides of the major faults are indicated. To date, there have been drilled 251 producers and 11 dry holes. The field has produced (to July 1, 1946) 33½ million barrels of oil from two sand bodies in the Sparta and several sand lenses in the Wilcox. Present daily production is approximately 8500 barrels.

ACKNOWLEDGMENT

The writer appreciates the opportunity afforded him by Continental Oil Company to prepare and publish this paper. Thanks are extended to Dr. Max Bornhauser, Continental Geological Department, for providing the subsurface map and for his constant assistance; to Dr. L. F. Athy and Mr. John M. Crawford, Continental Geophysical Department and Mr. Fred W. Bates, Consulting Geologist, for their valuable advice, help, and information.

GEOPHYSICAL HISTORY OF RAISIN CITY FIELD, CALIFORNIA*

JOHN SLOAT†

ABSTRACT

The discovery history of Raisin City Field is presented because it demonstrates the ability of the seismograph to locate low relief structures, where closure is present only in certain zones, even in areas where records are of mediocre quality. The seismic map which led to leasing is shown, along with detail maps made several years later. Gravimeter maps and maps from well points are also presented.

The Raisin City Field is located in Township 15 S, Ranges 17 and 18 E, Fresno County, and derives its name from the small settlement of Raisin City about 10 miles East of the Field. The area appears flat and barren on the surface. Actually, the surface dips gently to the southwest at the rate of four feet per mile, the average surface elevation being +195′. There is no surface indication of folding or faulting. The location of the Field is shown on the regional map in Fig. 1. The large, dark circles show the locations of wells which have now been surveyed for velocity in this general area.

The geophysical history of the Raisin City Field may be of interest because it demonstrates the aiblity of the seismograph to locate low relief closures, *even in the absence of closure or prominent folding in beds both above and below the producing horizons* (see Figs. 2 & 3). The earliest survey of this area which resulted in leasing was made by a contract crew working under the joint sponsorship of Seaboard-Tide Water-Union in 1937. The area was shot in the course of a reconnaissance survey, and no attempt was made to detail the structure. At that time, the only well in the area of appreciable depth had been drilled to 5786 feet in the SE¼ of Sec. 20-15-18, and abandoned in 1934. The well bottomed in continental beds of Miocene age, and a few gas shows were reported between 5400 and 5500 feet.

The map of Fig. 4, which resulted from this early survey, provided the basis for leasing by Seaboard-Tide Water-Union. This map was made by dip projection on the cross sections. The shot-hole pattern is shown in Fig. 4; non-continuous 300–300 split or offset T spreads were used. The contour map carried the label "Approximate Middle

* Read at the Annual Meeting of the Society, Los Angeles, Calif., Mar. 27, 1947.

† Union Oil Company of Calif.

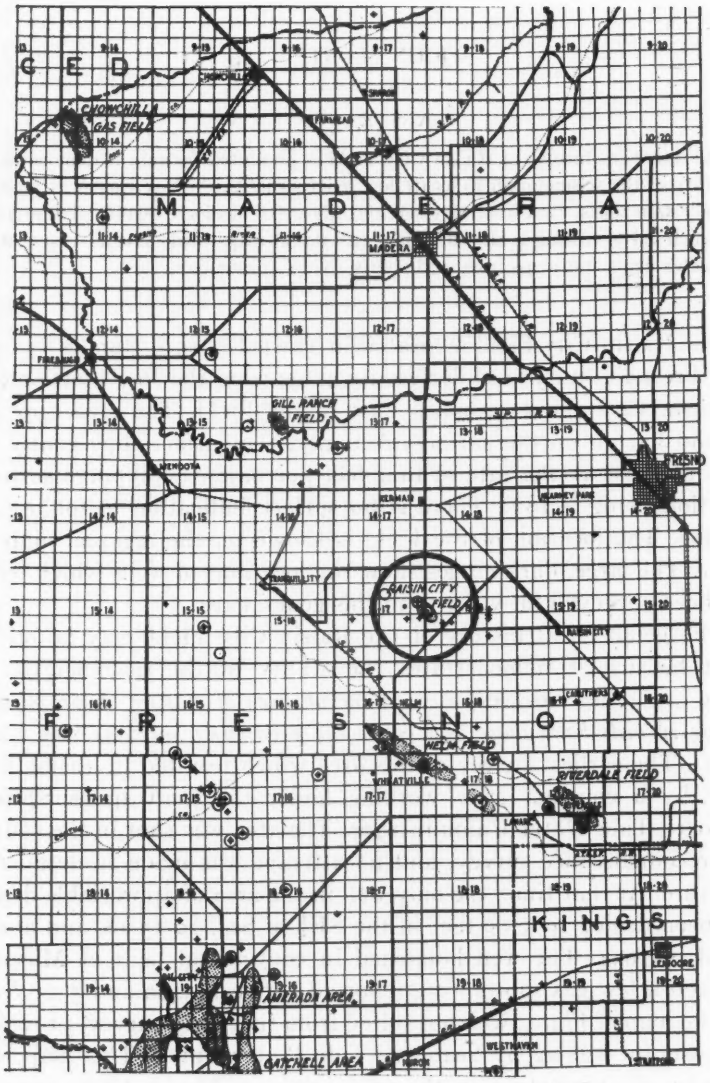


FIG. 1. Regional map of central San Joaquin Valley showing location of Raisin City Field. Large dark circles show wells now surveyed for velocity.

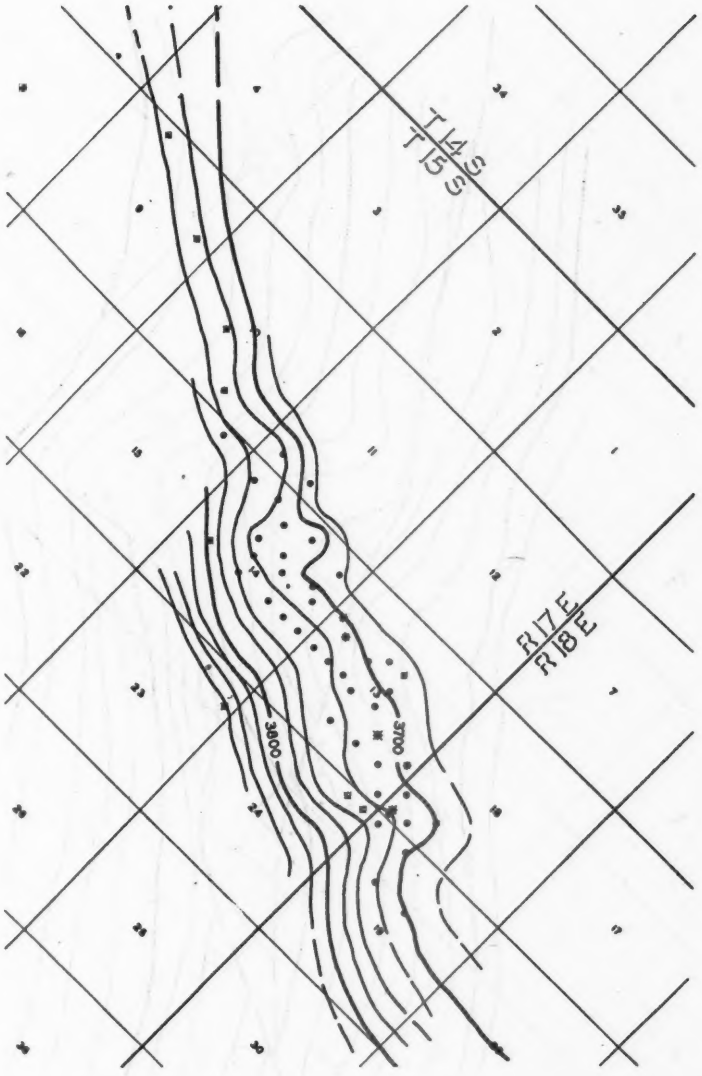


FIG. 2. Contours on Top Etchegoin (Pliocene) from well points. This horizon and beds above it show only slight widening of contours, yet productive closure is present 1000′ below this bed.

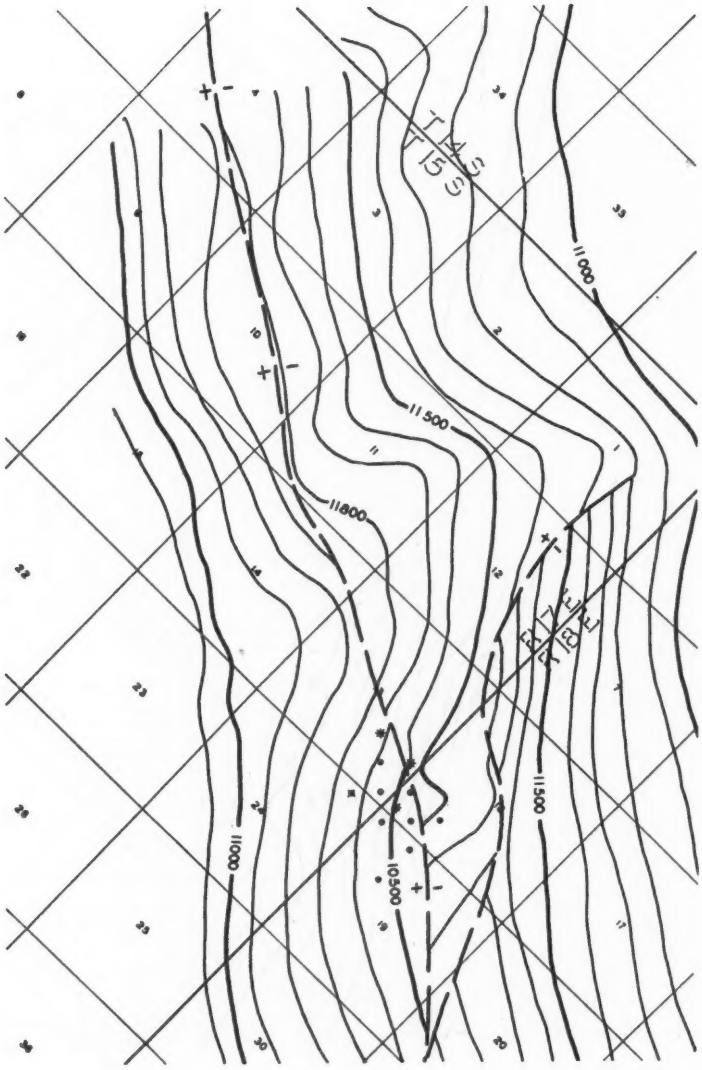


FIG. 3. Seismic contours on Top Basement. No reversal is present, but large thrust fault may be origin of productive closure in Miocene-Eocene zones.

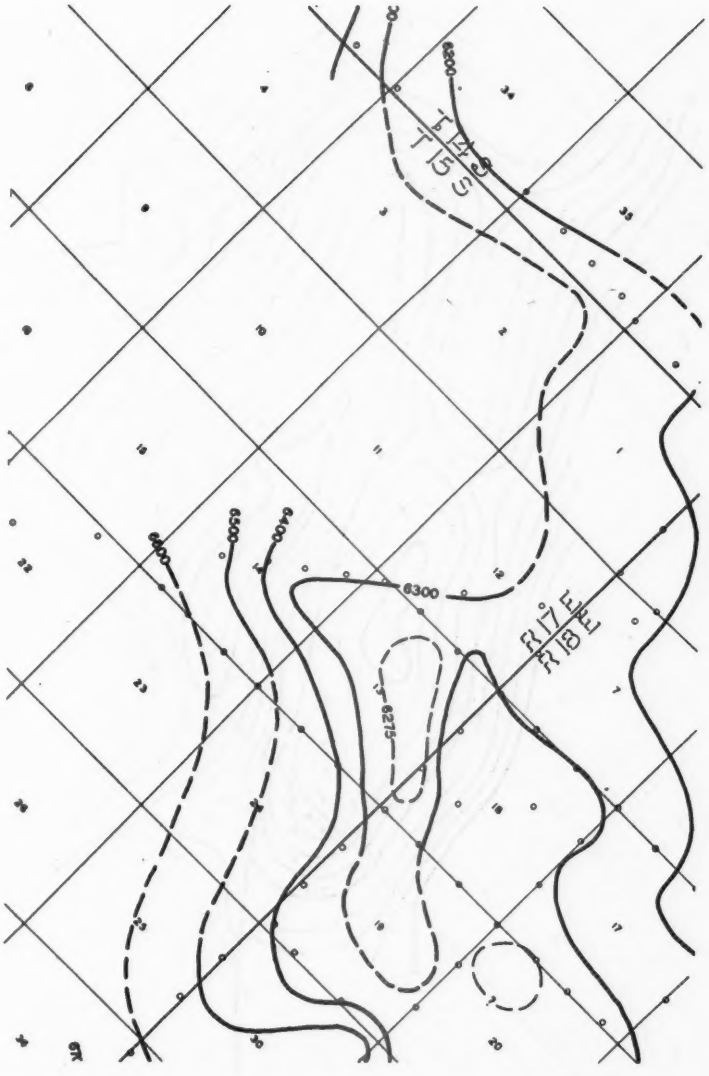


FIG. 4. Seismic Contour Map on Eocene Zone which led to joint leasing in area by Seaboard-Tide Water-Union Oil Companies. Survey conducted in summer of 1937 by Western Geophysical Co., and map made by dip projection on cross sections. Small circles show locations of shot points.

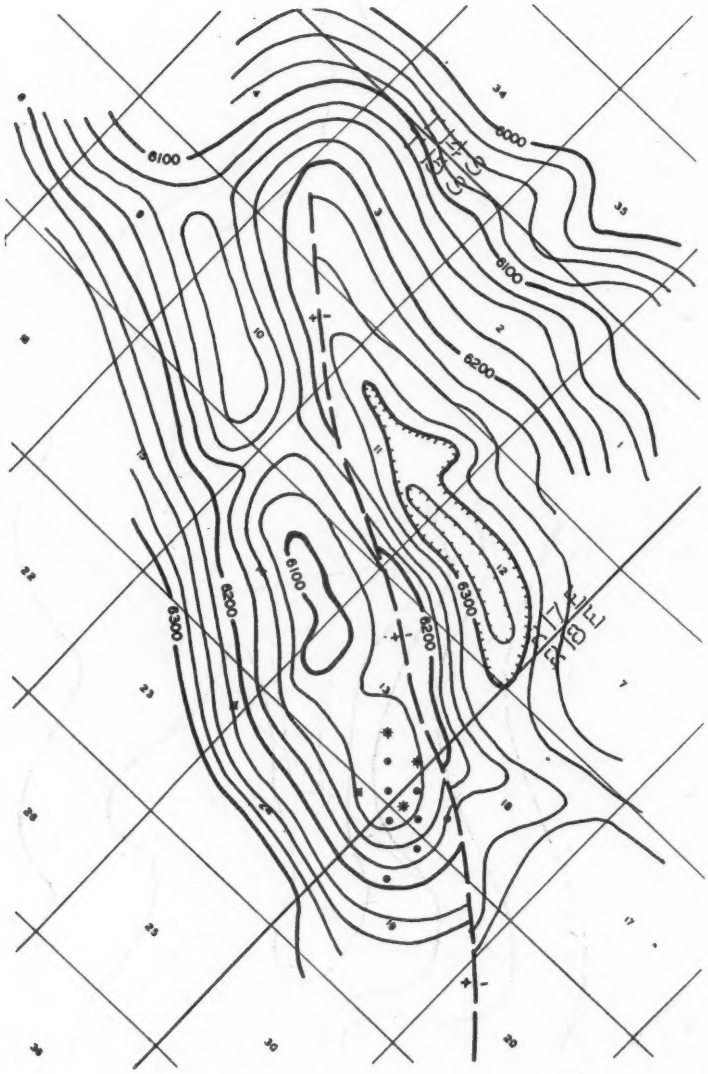


FIG. 5. Seismic Detail Contour Map on Base Domengine, made in spring of 1942 for Seaboard-Tide Water-Union. Survey by Western Geophysical Co. Shot points not shown. Notice that map was made before wells were drilled on crest of closure.

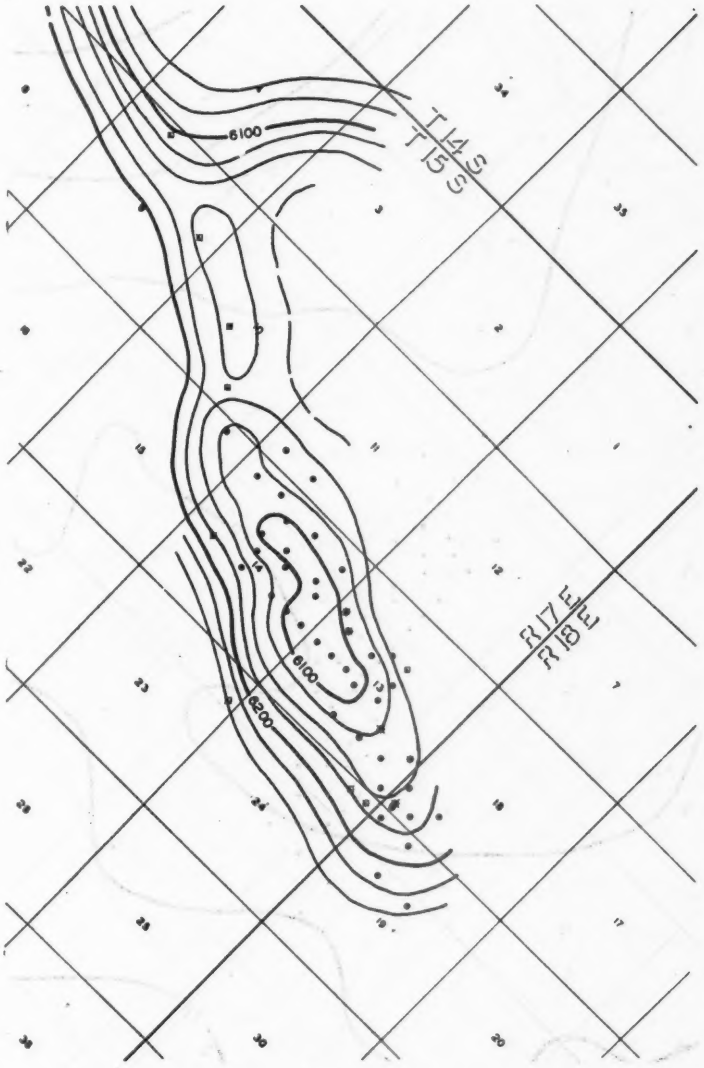


FIG. 6. Contours on Base Domengine (Eocene) from well points. Notice similarity to Seismograph Map in Fig. 5. Fault on Seismograph Map has yet to be proved or disproved by wells.

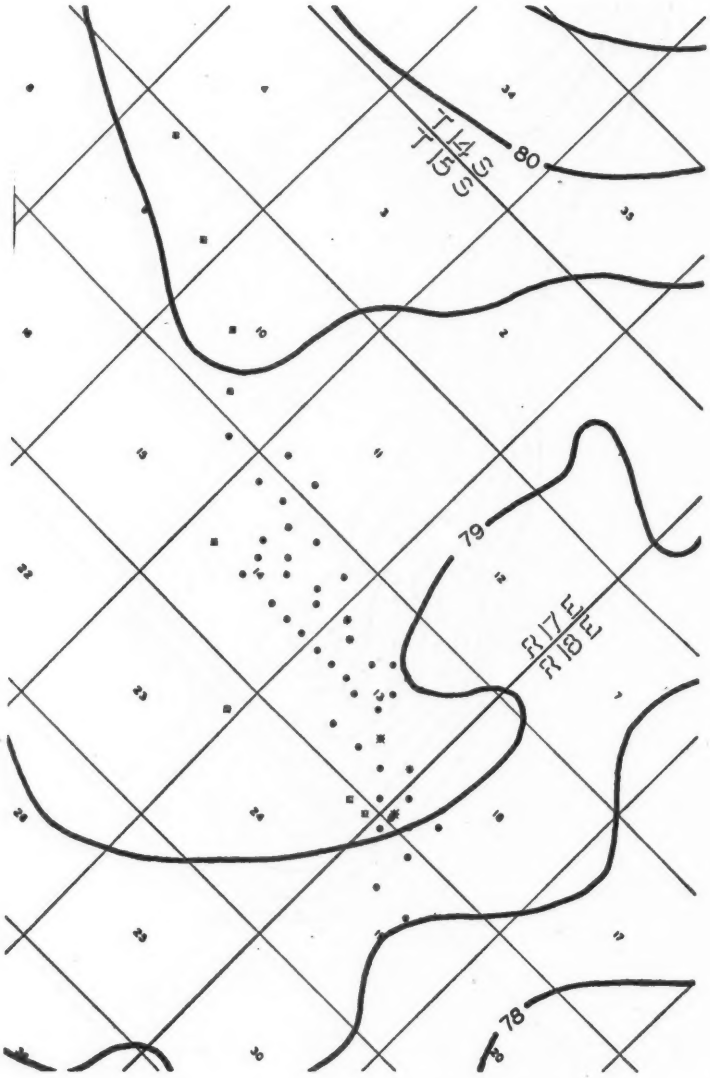


FIG. 7. Unreduced Gravimeter Map made by Brown Geophysical Co. in 1942 for Seaboard Oil Co. (Contour interval, 0.5 mg.)

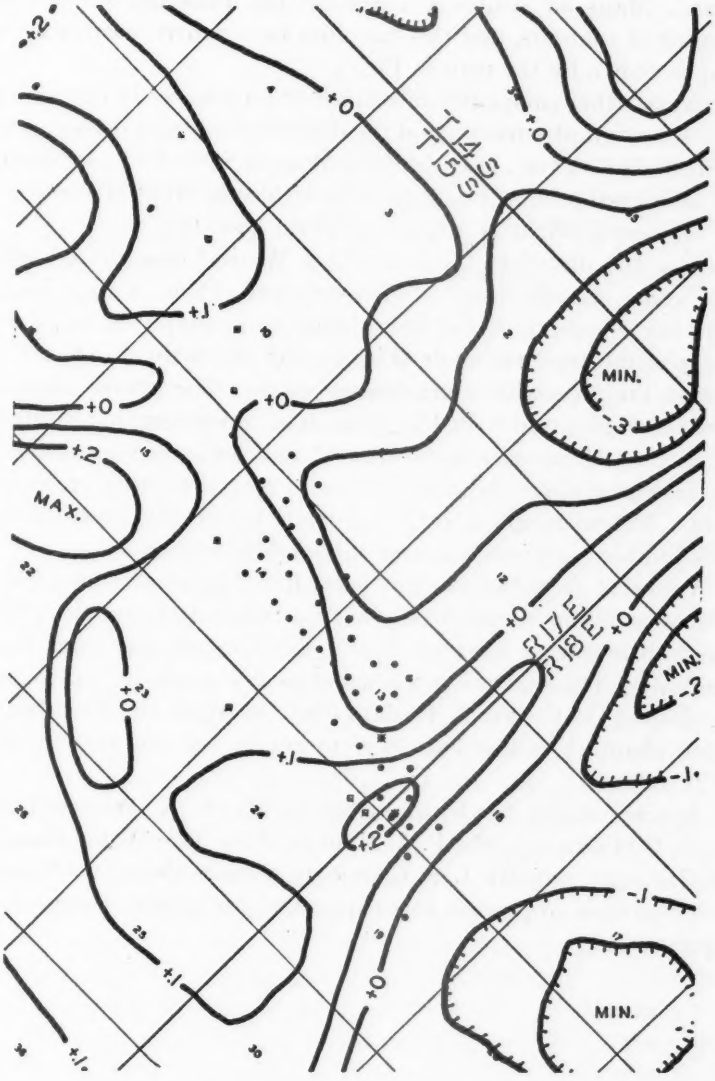


FIG. 8. Residual Gravity Map prepared by Brown Geophysical Co. from map in Fig. 7. (Contour interval, 0.1 mg.)

Eocene," and present well points place the middle Eocene around −6000′. Maps on shallower zones (in the Pliocene) showed only widening of contours, and this has since been proved correct by well data, as shown by the map in Fig. 2.

Several other companies subsequently took leases in the area and made seismograph surveys, and the discovery well was drilled in 1941 by Shell Oil Co., Inc., near the SW corner of Sec. 18-15-18. This hole was completed primarily as a gas well with some oil in Miocene sands of Continental origin at a depth of about 5000 feet.

After the discovery, Seaboard-Tide Water-Union drilled several wells in Sec. 13 offsetting the discovery well. Then, in 1942, because of the inadequate control of the original seismograph survey, a detail survey of the area was made (Fig. 5), and the Seaboard Oil Co. also covered the area with a gravimeter survey. The gravity maps are shown in Figs. 7 and 8. In Fig. 5 the detail seismograph contour map on the Base Domengine is shown, and this can be compared with the map in Fig. 6 where the same horizon is contoured from present well points. The seismograph map was made before any wells had been drilled in Sec. 14 where the crest of the fold is located.

A total of 51 wells have now been drilled in or near the Field; six of these were dry holes, three produced mostly gas, and the other 42 found oil in one or more of three lower Miocene and three Eocene sand zones. The shallowest producing zone is at about −4700′, while the deepest is at −6100′. To date (October 1946) the Field has produced about $3\frac{1}{2}$ million barrels of 19 gravity oil and about 6 billion cu. ft. of gas.

Appreciation is hereby expressed to Mr. L. N. Waterfall of the Union Oil Company, Mr. F. A. Menken of the Tide Water Associated Oil Company, and Mr. L. S. Chambers of the Seaboard Oil Company for permission to publish this paper, and for helpful comments and suggestions.

GEOPHYSICAL HISTORY OF THE ANAHUAC OIL FIELD, CHAMBERS COUNTY, TEXAS*

GLENN E. BADER†

ABSTRACT

Early geophysical exploration in the Anahuac area from 1925 to 1929 included refraction fan shooting and a torsion balance survey. A reflection dip survey in 1933 indicated a large structural closure on which the discovery well was drilled in 1935. No detailed geophysical work has been done on the structure since the discovery of the field.

The Anahuac oil field is of particular interest from the geophysical viewpoint in that it is purely a geophysical discovery. It is outstanding in that it ranks fourth among Texas Gulf Coast fields in regard to estimated ultimate recovery of oil. There are 357 producing wells drilled on 20-acre spacing and the producing area covers approximately 7565 acres.

The Anahuac Field is located in the north central part of Chambers County, Texas, six miles east of the town of Anahuac (Fig. 1). It was the first large field discovered in this area producing from the Frio formation of Lower Oligocene age. Many nearby fields such as Oyster Bayou, Fig Ridge and Winnie-Stowell have since been discovered in the surrounding area. The surface is a low flat plain typical of the Gulf Coast and is covered with recent sediments which show no evidence of the structure occurring in the older formations.

Wildcatters apparently found nothing to attract them to the present producing area at Anahuac as there is no record of even shallow wells having been drilled in the area. There are no known gas seeps; however, some rumors suggested the presence of oil and gas in nearby shallow water wells. H. J. McLellan of the Humble Geological Department investigated one of these wells in 1923. The water was found to have a high salt content but there was no evidence of oil or gas. This well, 420 feet deep, was located in section 73, three miles south of the present production. No deep wildcat wells were drilled in the area so there was no subsurface information to suggest a structure.

The Anahuac area was first covered by refraction fan shooting

* Presented at the Annual Meeting in Los Angeles, Mar. 27, 1947.

† Humble Oil & Refining Co., Houston, Texas.

by the Humble Oil and Refining Company in October, 1925. A shot point was located on the east flank of the structure at *A* (Fig. 2). The fans were shot with an average distance of four miles and covered the northeast part of the structure. These records did not indicate any abnormal velocities.

A Humble refraction crew returned to the Anahuac area in Feb-

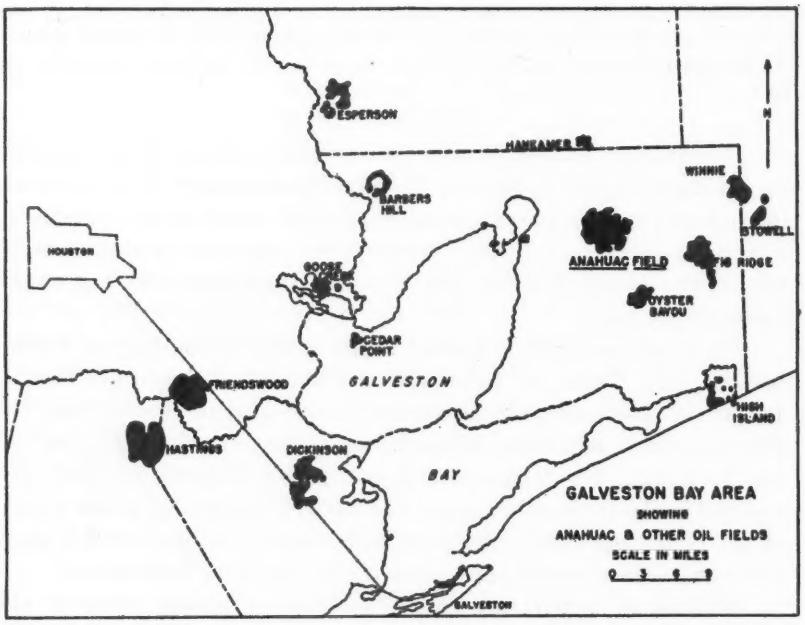


FIG. 1. Map showing Galveston Bay area and location of the Anahuac oil field.

ruary, 1927. With a shot point located at *B* (Fig. 2), the west side of the structure was fanned at distances of about four miles. Again the records did not indicate any abnormal velocities.

Many other companies probably covered the same area with refraction fans during this intense five year search. In April, 1927, a G. R. C. crew working for the Pure Oil Company located a shot point at *C* (Fig. 2) and covered most of the structure by a fan using distances averaging more than six miles in length. This work is reported as not indicating the presence of a salt dome. The refraction fans shown on Fig. 2 do not represent all of this type of exploration

work done in Chambers County through 1927 but are selected as being the only known work in the immediate vicinity of the Anahuac field.

The third and last phase of the refraction program was carried out in August and September, 1929. At this time, much of the north half of Chambers County was fanned and cross-fanned by refraction

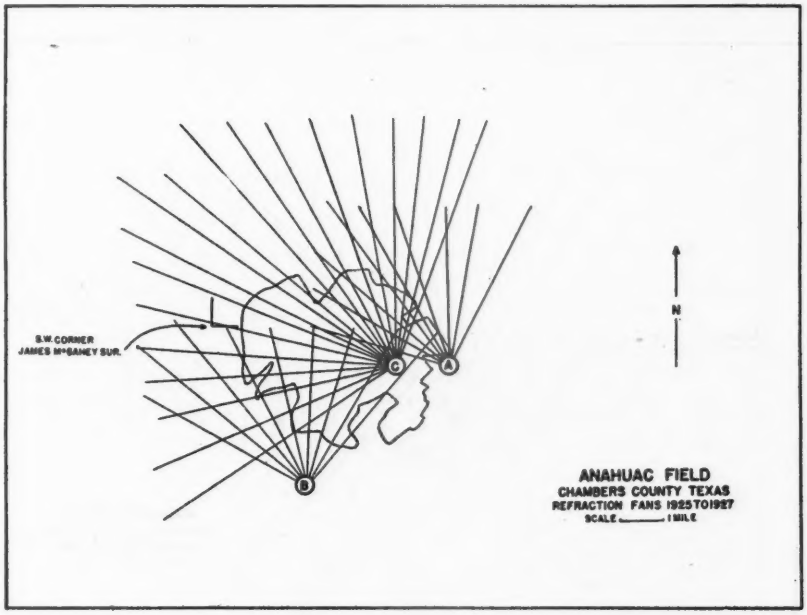


FIG. 2. Refraction fans shot during 1925 and 1927 by Humble Oil and Refining Company and Pure Oil Company with outline of present producing area.

shots to evaluate a large exploration lease that the Humble Company had taken. Fig. 3 shows only the shot points and fans that covered the immediate vicinity of the Anahuac oil field. Distances used for these refraction shots varied from five to seven miles and again no abnormal velocities were recorded.

A reconnaissance torsion balance survey was also made during the fall of 1929. The survey was not made in detail and many gradients were small and erratic. Fig. 4 shows an interpretation of this gravity work giving an indifferent sort of minimum anomaly. Coupled with the results of the refraction shooting, the gravity anomaly was

not considered of particular interest in 1929 and rentals were not paid on the exploration block. Looking back after the discovery of the field, the weak minimum anomaly probably indicates the presence of a salt uplift at some great depth.

The results of the refraction fan shooting show that it is not a suitable method for the discovery of structures where the salt is as deep as it probably is at Anahuac. The area was covered three differ-

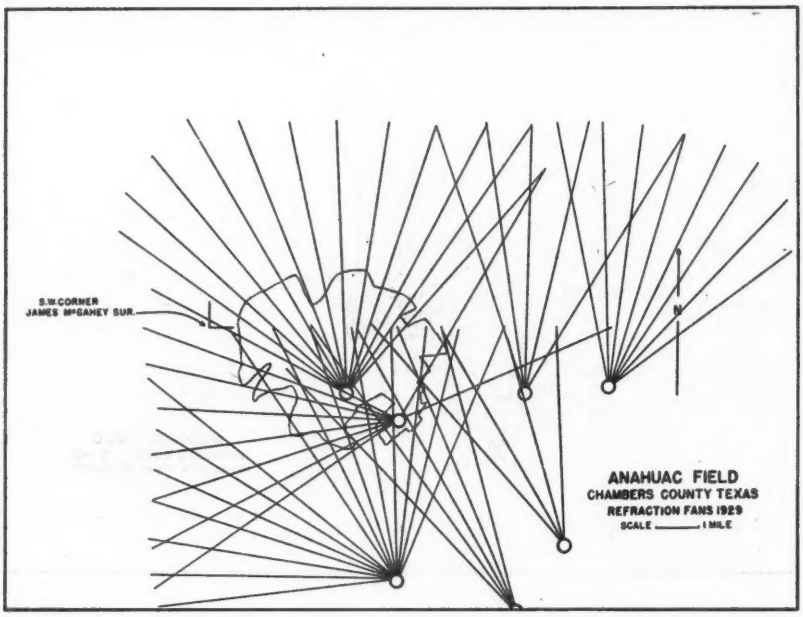


FIG. 3. Refraction fans shot late in 1929 by the Humble Oil and Refining Company with outline of present producing area.

ent times by the Humble Company with four to seven mile refraction shots without recording any abnormal velocities. Other companies covered the area with similar results. An examination of the refraction fans in Figs. 2 and 3 show that none of these shot points and fans were located so as to get maximum penetration over the center of the structure but it is doubtful that the results would have been different even with ideally located fans.

Shortly after Anahuac was explored by refraction seismograph and torsion balance, the reflection seismograph was introduced as a

new exploration instrument. The first success of reflection shooting was achieved in Oklahoma and East Texas where the limestone formations gave outstanding correlatable reflections. The first successful adaptation of reflection shooting to the lower coastal areas came with the development of the dip-shooting technique. This was a good rapid reconnaissance method for the discovery of large high relief structures. This method was first used by placing shot points in a checker-

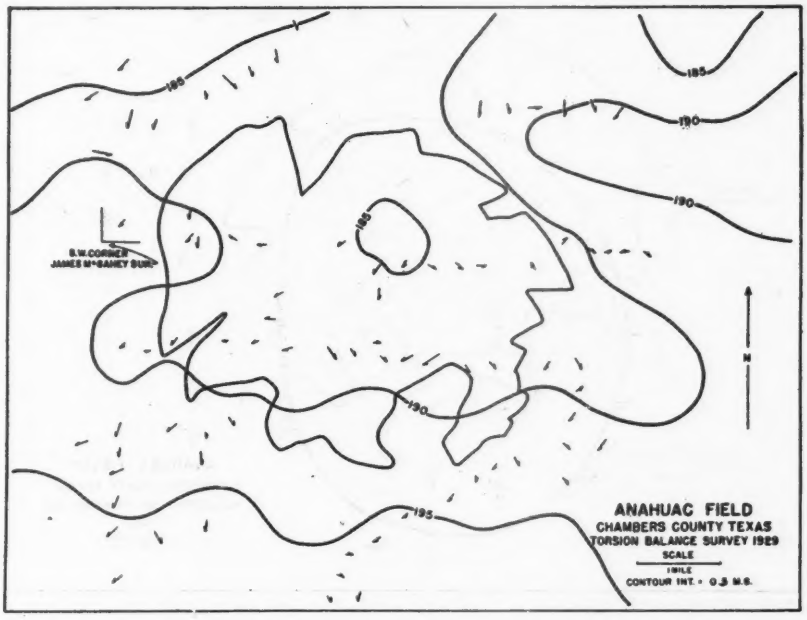


FIG. 4. Torsion balance map showing gravity gradients in relation to present outline of production.

board pattern at intervals of about a mile. The receiving instruments were generally laid out along north-south and east-west profiles. The wide spacing of the shot points and the erratic character of the Gulf Coast reflections made correlation of questionable value; however, these profiles generally furnished sufficient data for the computation of dips or components of dip.

In March 1933, the Humble Company made a reconnaissance reflection dip survey in northern Chambers County, the object of which

was to evaluate a small block of leases several miles east of the present producing area. While attempting to establish regional control to the west of these leases, abnormal dips were recorded which outlined the Anahuac structure. The area was covered with scattered dip profiles, using distances of 1650–2400 feet. The profiles were shot in east-west and north-south directions and the component of dip computed at the desired depth to the closest whole degree of dip angle.

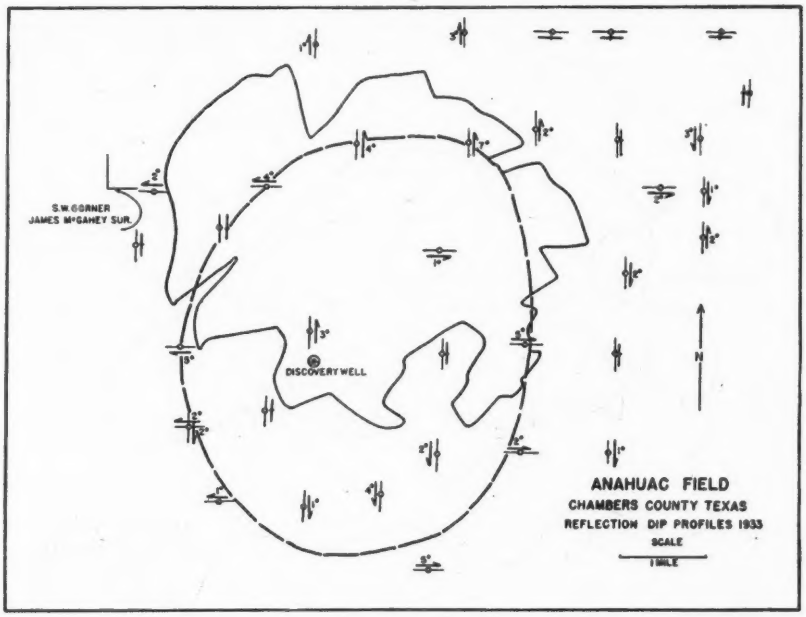


FIG. 5. Reflection dips and dotted area of interest in relation to outline of present production.

Anahuac was discovered with a minimum of data. The dip profiles were spaced at wide intervals (Fig. 5). No correlation was attempted as there were no outstanding reflections. A domal uplift was indicated by definite quaquaversal dips which showed a structure of several hundred feet of closure. The original outline of the area of interest was roughly circular and was located by connecting the large dips which surrounded the flanks of the structure. This area of interest, as shown by the dotted outline in Fig. 5, does not include the entire structural closure but was considered at the time of discovery

to include the probable producing apex of the structure. The circular area was approximately four miles in diameter and the original block taken after this shooting included 14,000 acres.

The discovery well, the Humble Oil and Refining Company A. D. Middleton No. 1, was drilled in Section 58 in the Houston and Texas Central Railroad Survey. Drilling began December 8, 1934 and the well was completed at a depth of 7088 feet in the Frio sand March 17,

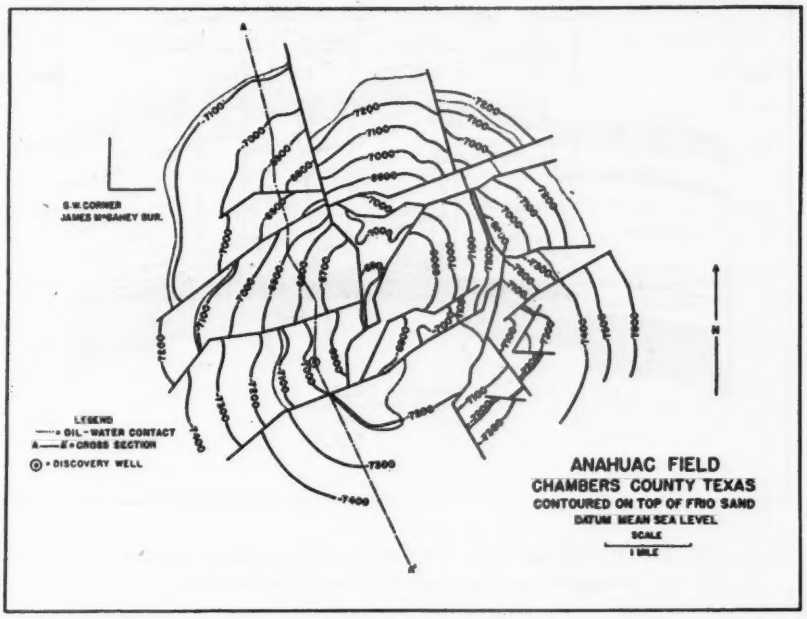


FIG. 6. Geologic subsurface map of the Anahuac field contoured on top of the Frio sand

1935 with an initial daily production of 547 barrels through a $\frac{1}{4}$ inch choke.

The Frio sand of Lower Oligocene age is the principal oil-producing formation in the field, although minor amounts of oil and gas have also been produced from the Margulina formation. In the central part of the uplift the upper part of the Frio formation is saturated with gas. The gas zone overlying the oil zone in the Frio formation covers approximately half the oil producing area and reaches a maximum thickness of 350 feet at the apex of the structure. The oil producing zone has a maximum thickness of 120 feet with the oil-water contact at an approximate depth of 7110 feet below sea level.

The thick producing sand and large area of production (7565 acres) give Anahuac fourth rank among upper Gulf Coast oil fields of Texas in regard to estimated ultimate recovery of oil. Only the Conroe, Hastings and Friendswood fields exceed Anahuac in estimated ul-

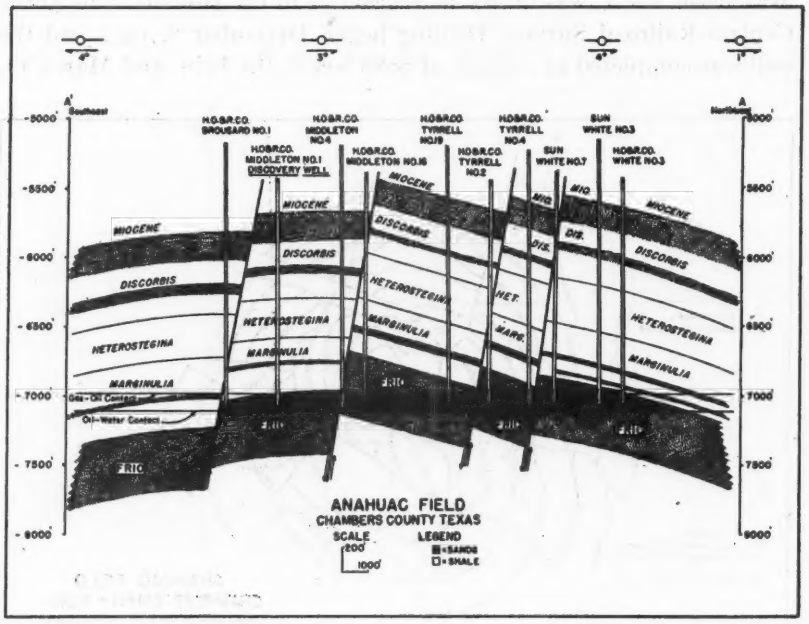


FIG. 7. Northwest-southeast cross section of the Anahuac field showing approximate location of critical reflection dips.

timate recovery. The total production to date is a little more than 60,000,000 barrels.

The structure at the top of the Frio sand is a dome broken by many radial faults (Fig. 6). The detail of the structure is complex but the general configuration is that of a simple dome. The apex of the structure as shown by the highest well is a half mile south of the center of the producing area as the producing sands on the south part of the structure are faulted down below the oil-water contact (Fig. 7). The center as outlined by dips falls about a half mile south of the apex of the structure.

The dip profiles were generally not disturbed by the complex fault system because they happened to fall on undisturbed segments of the

structure and not across the faults. A few erratic dips, such as the one just north of the discovery well, can be explained by the adjacent fault. The only sizable producing area which fell outside the reflection dip outline was the large upthrown wedge-shaped segment at the northwest side of the field.

The only reflection survey made at Anahuac by the Humble Oil and Refining Company was the first reconnaissance survey made in 1933. The total length of time in making the survey was a month, while the critical dips falling in the immediate area of the structure required not more than ten days' work. The original leases taken on the dip outline included 75 per cent of the total producing area and would have included all of it had a slightly more generous area been taken.

The geophysical history of Anahuac is instructive for it offers a striking demonstration that an area once worked over by geophysics may later become a major geophysical discovery when new or improved geophysical techniques are used, or when new productive horizons are sought. Thus the refraction seismograph, although highly successful in finding salt domes at depths less than 5000 feet, failed at Anahuac because it lacked the necessary depth penetration. Comparatively crude reflection dip shooting was successful at Anahuac because of high structural relief.

ACKNOWLEDGMENTS

The writer wishes to thank the Humble Oil and Refining Company for permission to publish the paper; D. P. Carlton, H. G. Patrick, R. L. Denham, A. P. Wendler, Wm. M. Rust, Jr., and D. H. Gardner for help and suggestions in the preparation of the paper; and J. D. Johnston for preparation of the figures.

GEOPHYSICAL HISTORY OF THE EAST FIELD, JIM HOGG COUNTY, TEXAS*

W. E. HOLLINGSWORTH†

ABSTRACT

The geophysical work which led to the discovery of the East Field in Jim Hogg County, Texas was started in 1934, when a single line of torsion balance stations was run across the area. Core drilling followed in 1938 and 1939. Reflection seismograph work was done in 1942 and outlined the field. The discovery wells were drilled in 1942 and 1943.

The geophysical history of the East field in Jim Hogg County, Texas started in the early part of 1934 when a line of torsion balance stations was run across the area. Results of this survey were inconclusive as only the one line of stations was run. Further gravity surveying was prevented by permit difficulties and the crew was moved to other areas.

In the latter part of 1938 and early 1939, shallow core drill exploration was done in the area. Core holes were drilled to depths of 1000 to 2000 feet and a Schlumberger log was run in each. The contours shown in Fig. 1, based upon the correlation of the electric logs, show a broad nosing to the east in the contours. The present position of the field is shown by the dashed enclosure. Only one well had been drilled in the area, this being the 1-A dry hole drilled to the west of the present field. This well was drilled prior to either the core drill or seismograph work.

Seismograph exploration started in the area on February 10, 1942 and continued until June 15, 1942. Not all this time was spent in the area around the East field as considerable acreage was covered in adjoining areas. A continuous coverage technique was used with shotpoints spaced 1200 feet apart and with straddle spreads of 2400 feet in length. Shotholes were drilled to depths of 60 to 100 feet and charges of from 5 to 15 pounds were used. No great difficulty was encountered in drilling shotholes as most of the holes were in clay. A considerable mantle of surface sand, which in some cases formed sand dunes, was present and made transportation of equipment difficult. Some difficulty was also encountered in surveying due to lack

* Read at the Annual Meeting of the Society, Los Angeles, Calif. Mar. 27, 1947.

† Sun Oil Co., Beaumont, Texas.

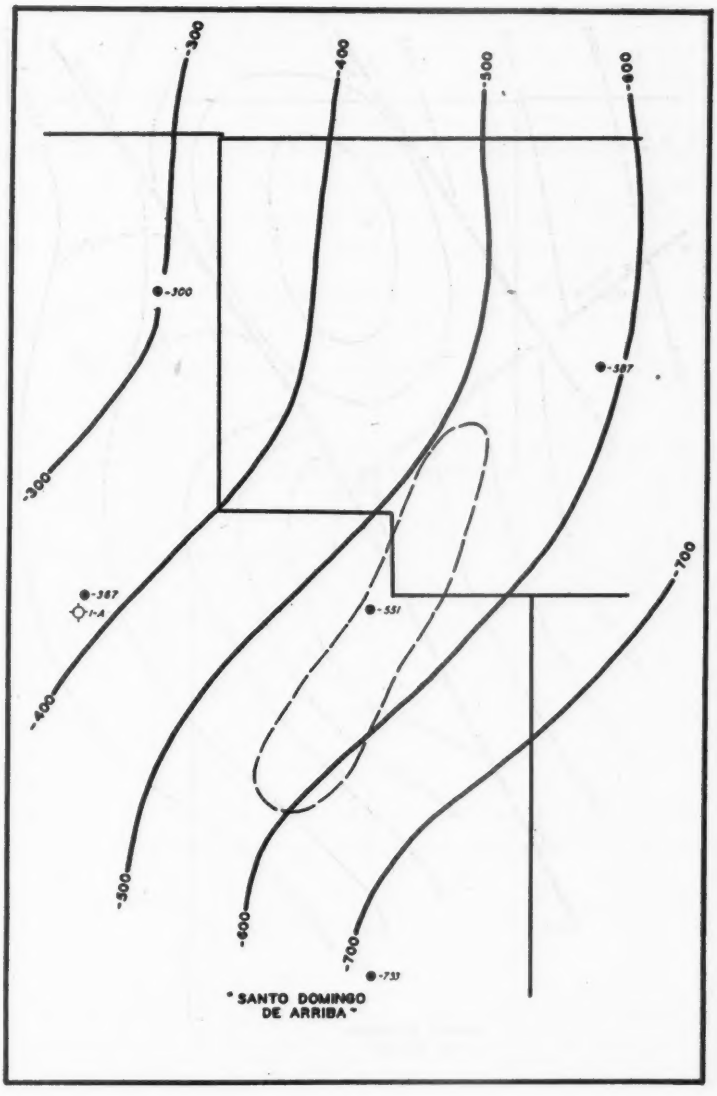


FIG. 1. Map showing shallow core drill results. Outline of present field is shown for comparison.

of section corner markers. Record quality was considered as fair over most of the area although it deteriorated somewhat to the west.

On June 17, 1942, interpretation of the records around the present

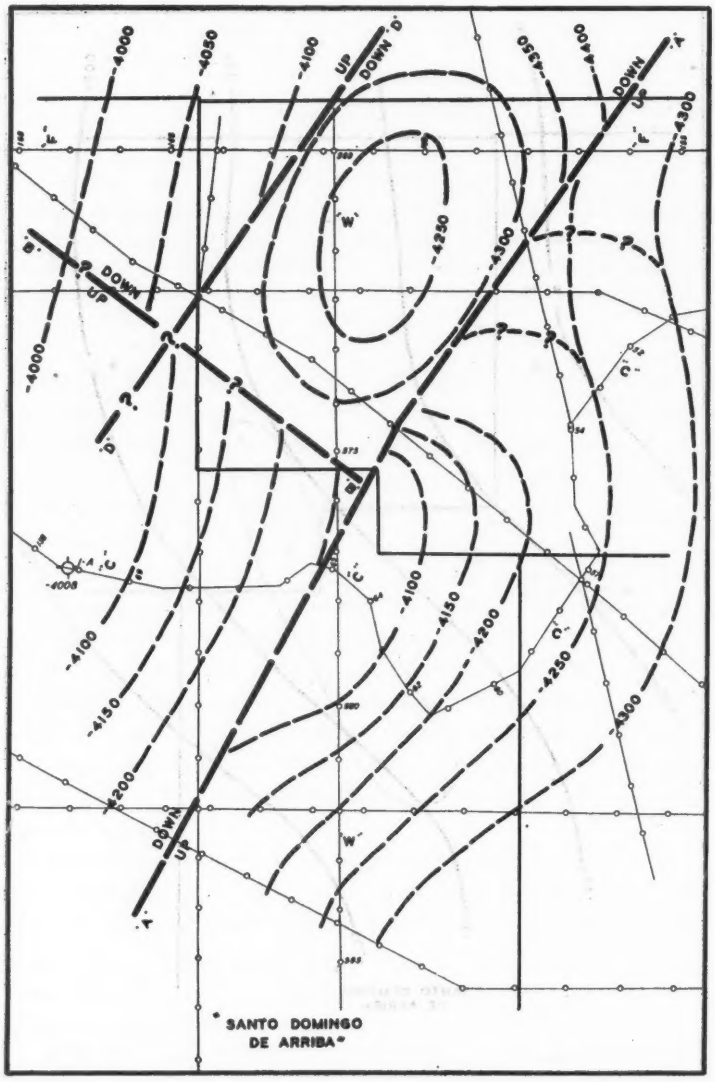


FIG. 2. Map showing contours drawn from seismograph work.

East Field had been completed and a preliminary report covering that portion was issued, this map being shown in Fig. 2. On this preliminary map a small closure of about 50 feet is indicated and a possible closure of 50 feet is shown against the fault, *A–A*, downthrown to the west.

Figs. 3, 4 and 5 are presented to show some of the data on which the seismograph map is based. Fig. 3, Section C-C, was the first line run across the area and runs approximately through what is now a line of wells, 1-A, 3-A, 4-A, and 2-A. A break in reflection continuity and erratic dips at shotpoint No. 64 indicated possible faulting. The direction of throw was uncertain, although dip closures between the 1-A well and other wells to the east indicated that the fault was down to the west. With the exception of those dips on shotpoint

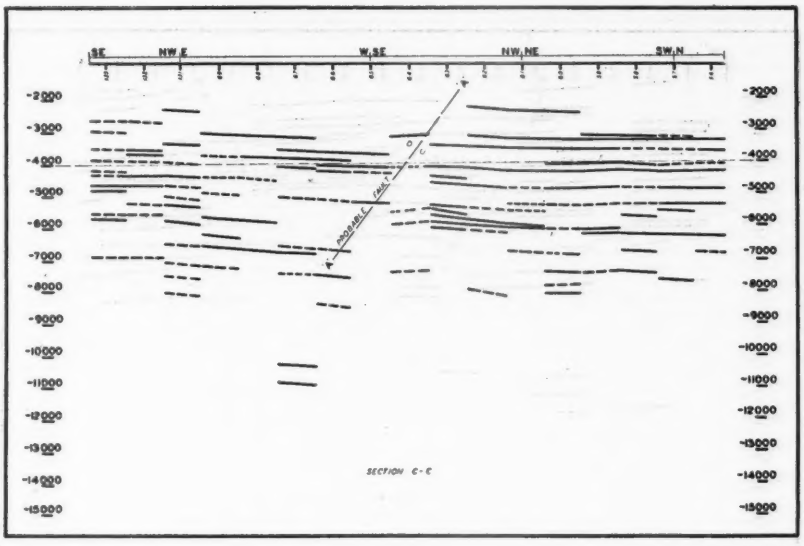


FIG. 3. Seismograph profile C-C—an east-west (approximately) section across middle of East Field showing fault down to west.

No. 64, which are thought to be unreliable because of coming through the fault zone, no dip reversal was indicated. This indication has been proved to be correct by the well data obtained subsequently.

Section F-F, Fig. 4, was the first seismograph line in the area which indicated reverse dip. On this section, shotpoints 160 to 162 showed a slight reversal with about 50 feet of west dip indicated. In this case, Fault A-A was again suggested by reflection discontinuities although the evidence here is not as clear as that on section C-C. Fault D-D was put in as "probable" mainly on the basis of reflection discontinuity on this section and on Section W-W, Fig. 5.

Section W-W, Fig. 5, is a north-south line approximately through what are now the 1-D and 4-A wells. On this section a very faint north dip is indicated between shotpoints 572 and 776. The break is reflection continuity is good evidence for fault D-D. Since this section runs through the junction of faults A-A and B-B, the records here were too confused to help much in locating these two faults. Fault B-B was put in to separate the east dip on Section C-C from the anomalous southwest dip on the closure to the north.

The drilling program was begun July 31, 1942 when the 1-D

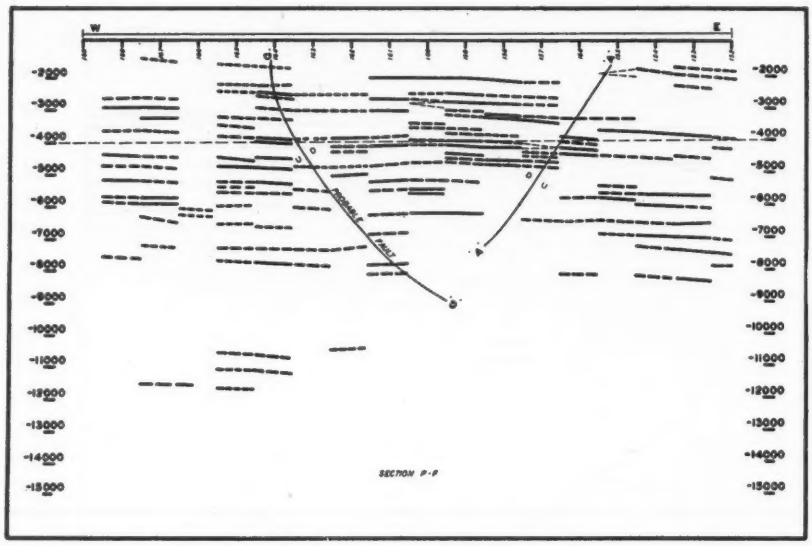


FIG. 4. Seismograph profile F-F—an east-west section along north side of East Field showing two faults and reverse dip.

location was started on the closure to the north. It was completed October 6, 1942 as a very poor producer with a high gas-oil ratio. After the failure to establish good production on the closure to the north it was decided to test the closure adjacent to the fault. The 2-A location was then staked and drilled. It was dry and abandoned, but did have enough shows to be encouraging. Following this the 3-A test was drilled west of the fault. A study of subsurface data between the 2-A and 3-A wells together with the seismograph dip data indicated that the suspected fault was probably between the two wells and the 4-A location was made. It was brought in as a producer on

February 7, 1943 from a sand in the Cockfield zone and flowed approximately 90 barrels per day.

Following the completion of the 4-A well, nine other wells were completed along the fault with the 10-A dry hole limiting the field to the south. One additional producer and two dry holes were drilled on the closure to the north and one additional dry hole was drilled west of the fault.

Fig. 6 is a map drawn by the geological department from the data obtained from the wells. Comparing it to the seismograph map shown

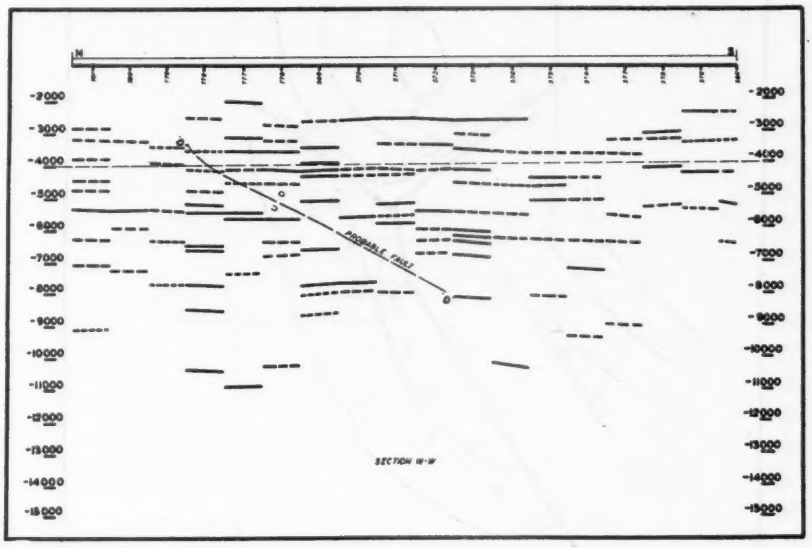


FIG. 5. Seismograph profile W-W—a north-south section through East Field showing one fault and north-south reversal.

in Fig. 7, on which the producing wells have been placed, it can be seen that a very close check was obtained. Faults A-A and B-B have been proven by the drilling, as well as the main features of the contouring. Fault D-D is still unproven as no drilling has been done in this direction.

The discovery of the East field illustrates the ability of the reflection seismograph method, in some cases at least, to find small fault closure fields.

In conclusion, the author wishes to thank the officials of the Sun Oil Company for permission to publish this paper.

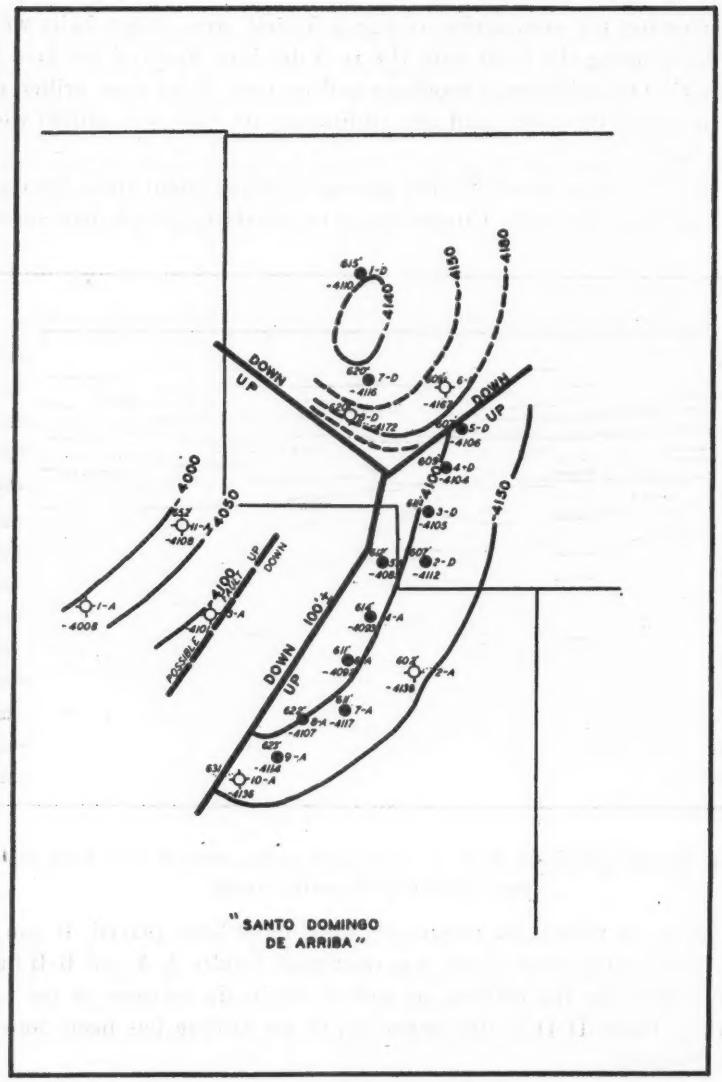


FIG. 6. Contour map based upon geological data obtained from wells drilled in East Field. Compare with Fig. 7.

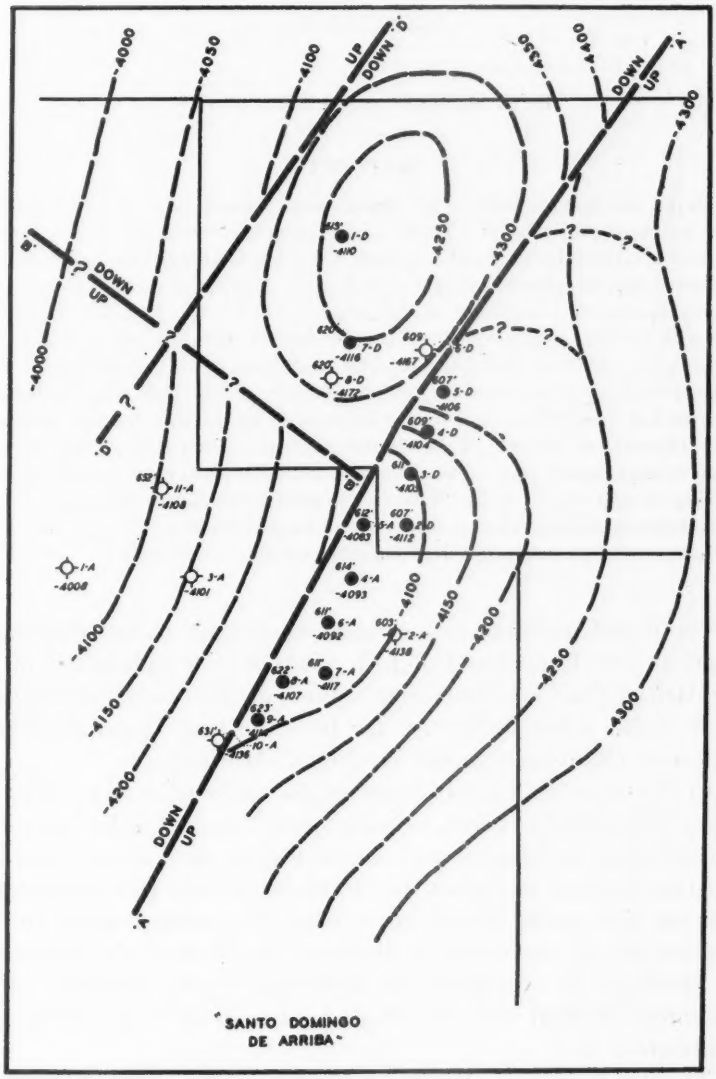


FIG. 7. Seismograph contour map same as Fig. 2 with wells added. Compare with Fig. 6.

GEOPHYSICAL EXPLORATION AND DISCOVERY OF THE BUDAFAPUSZTA (LISPE) OIL FIELD IN HUNGARY*

D. C. SKEELS† AND RAOUL VAJK†

ABSTRACT

Interest was first attracted to the Budafapuszta area by its geographical position on the eastward projection of a known surface anticline, which had produced small quantities of oil at Peklenicza and Szelnicza. A test was located in 1920 on a small surface feature, and completed in 1923 as a dry hole. In 1934 a torsion balance survey was made by Eurogasco, a subsidiary of the Standard Oil Co. (N. J.) which indicated a dome with its crest 1500 m. north of the dry hole. A reflection survey verified the presence of the structure. The discovery well was located by the torsion balance data, and completed as a producer in 1937. A gravity meter survey made after the first two producers had been drilled, gave further information on the structure and assisted in the development of the field. This exploration history shows that a properly made torsion balance survey may be very efficient and economical even in hilly country. A geological map of part of the Szelnicza-Peklenicza anticline, a topographical map, torsion balance, seismograph and gravity meter maps, a seismograph cross section and a subsurface contour map of the Budafapuszta structure are submitted.

The Budafapuszta oil field owned and operated by the Hungarian-American Oil Industrial Co. Ltd. (MAORT), a subsidiary of the Standard Oil Co. (N.J.), is located in the southwest corner of Hungary, north of the Mura River, not far from the long known oil field of Peklenicza (Banyavar) in the Murisland (Murinsel).

In the following a brief history of the exploration of the Budafapuszta oil field will be given, as it is a typical example of the usefulness of geophysical exploration methods in finding oil bearing structures.

Attention was first given to the Budafapuszta area immediately after the first world war in 1919, when the Anglo-Persian Oil Co. obtained an oil concession in Hungary and formed the Hungarian Oil Syndicate to explore for oil in Hungary. The proximity of the Peklenicza oil field was encouraging for a prospect in the Budafapuszta area.

The structure of the Peklenicza oil field is a nearly east-west striking anticline which plunges to the east (see Fig. 1). Proceeding from east to west and west-southwest along the axis of the anticline first

* Read at the Annual Meeting of the Society, Los Angeles, Calif. Mar. 27, 1947.

† Standard Oil Co. (N. J.).

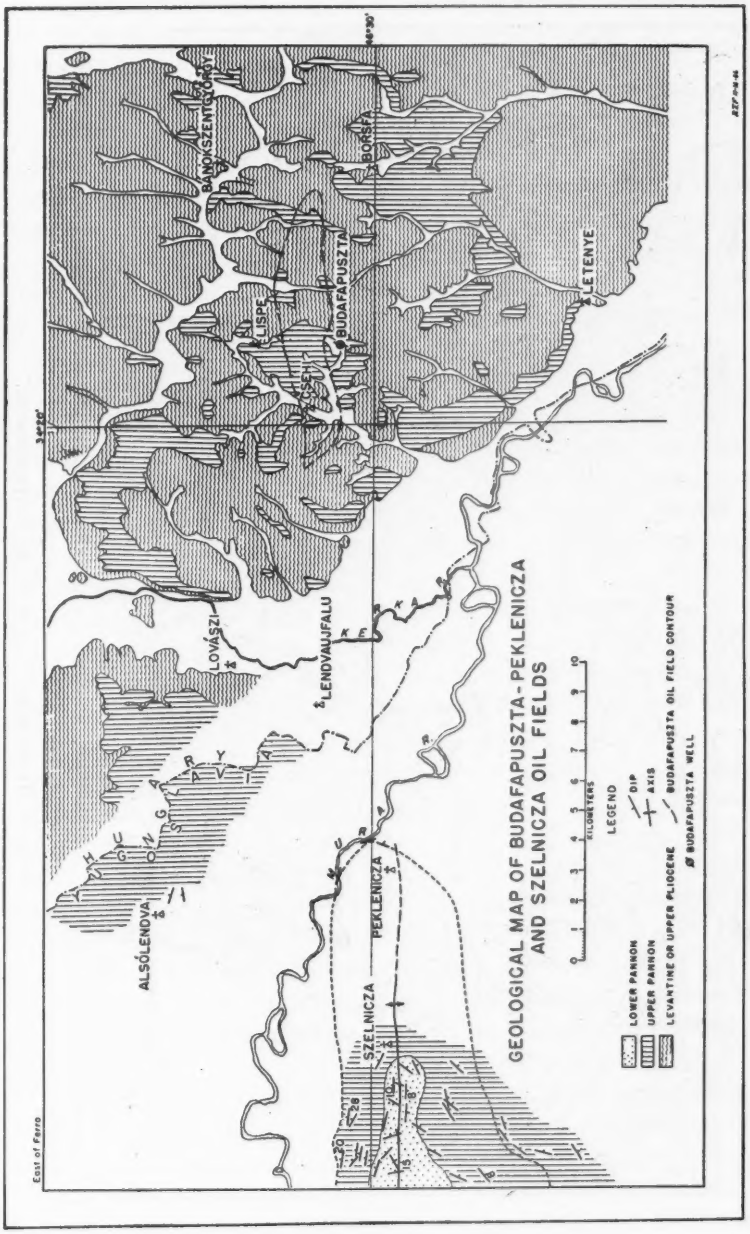


FIG. 1. Geological map showing relation of Budafapuszta field to Szelnicza anticline.

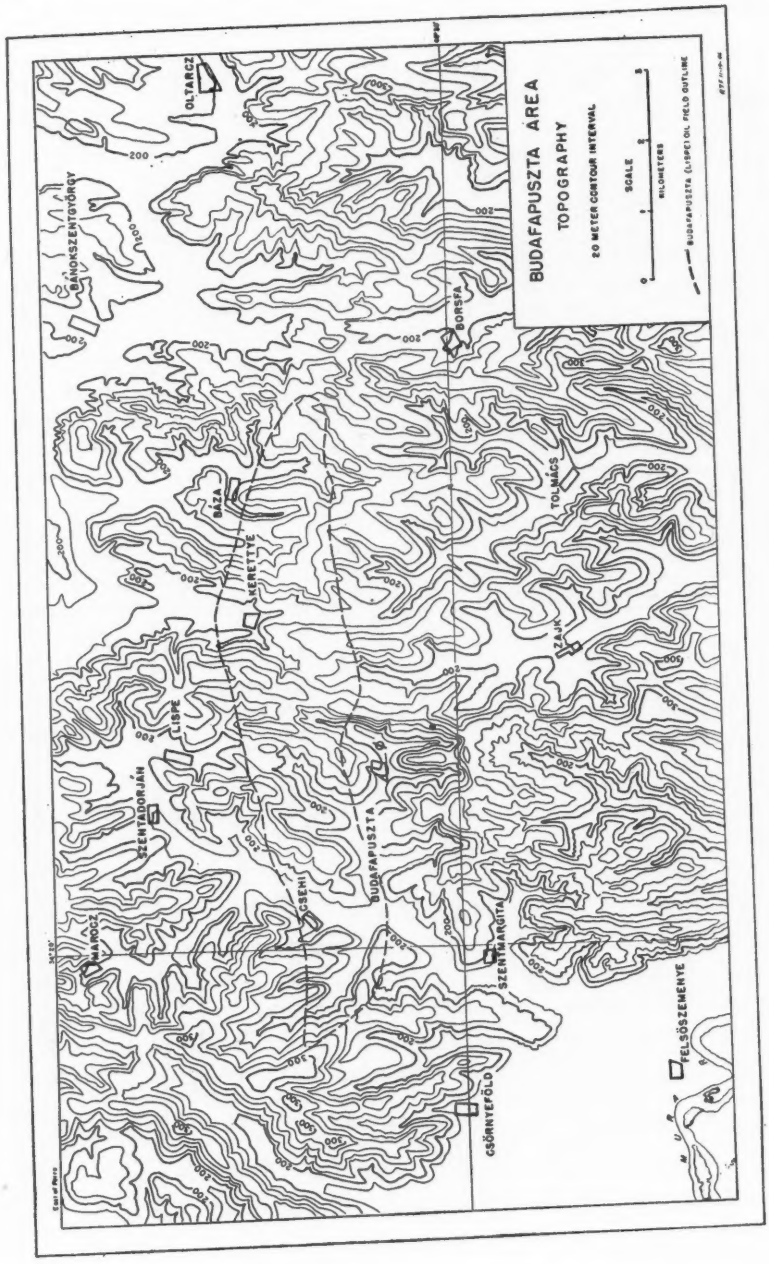


FIG. 2. Topographic map of the Budafapuszta area.

Upper Pannonian then Lower Pannonian, finally (beyond the limits of the sketch) Upper Mediterranean are exposed on the surface with strong dips to the north and south also. Two oil fields, at Szelnicza and at Peklenicza (Banyavar) are located on this anticline.

It was logical to suppose that this fold continues under the surface toward the east and extends beyond the Mura River and the Trianon border of Hungary. The area in the vicinity of Budafapuszta is covered mostly with Levantine, or Upper Pliocene and partly with Upper Pannonian. The topography is rather hilly (see Fig. 2). The hills rise from the 150 m. level of the Mura Valley to 350 m. making a total relief of 200 m. (600 ft.). The hills are cut by narrow erosional valleys.

A geological survey was made in this area in 1919 by the Hungarian Oil Syndicate. Based on the rather unreliable dip observations made on the Upper Pannonian strata exposed on the surface, or in the artificially made 2–3 m. deep shafts, a dome was contoured with the center about at the settlement Budafapuszta. Due to the rough topography, the Hungarian Oil Syndicate thought it hopeless to make a torsion balance survey in this area, although in accordance with the contract made with the Hungarian Government the staff and equipment of the Royal Hung. Baron Eotvos Geophysical Institute were at its disposal. Torsion balance surveys were made only on the Great Hungarian Plains where topographical conditions were ideal for torsion balance work. At that time the gravity meter was not yet developed for field survey and for this reason only a single pendulum station was made at Budafapuszta. Therefore, only the limited surface geological data were considered when a test well was staked out by E. H. Cunningham-Craig and Dr. H. Bockh, geologist of the Anglo-Persian Oil Co. and of the Hungarian Oil Syndicate, at the center of the dome contoured by surface geological data. The well, just east of Budafapuszta (Fig. 2), was drilled to a depth of 1737.5 m. (5700 feet) and was abandoned in Lower Pannonian as a dry hole. Only insignificant gas traces with oil smell were encountered during the drilling.

The Hungarian Oil Syndicate made a location on another structure (in the vicinity of Kurd) also, but this too turned out to be failure. After this second unsuccessful attempt, this company gave up the Hungarian concession in 1924.

In 1933 the European Gas and Electric Co. (briefly Eurogasco, later to become MAORT), obtained an oil and gas concession covering

Transdanubia, i.e., the southwestern quarter of Hungary. The concession covers the territory south and west of the Danube, as far as the Trianon border of Hungary.

The Eurogasco realized that the failure of the Hungarian Oil Syndicate was due to the fact that in Transdanubia no reliable information concerning the subsurface structures can be obtained from surface geological data, as the Upper Pliocene gravel, Pleistocene clay, sand and loess covering the Tertiary strata prohibit the geologists from drawing conclusions as to the structures of the Tertiary formations.

The geological survey made by the Eurogasco proved that in the Budafapuszta area the Pliocene strata are gently folded but the observed surface geological data are not sufficient to determine the exact location of these folds. For these reasons geophysical methods were adopted to detect such structures and to determine their extent and exact location.

In 1933, when the Eurogasco started the operations in Transdanubia, no gravity meter or seismograph equipment were obtainable in Hungary, consequently geophysical investigations were restricted to the use of torsion balances.

As was mentioned, the Budafapuszta area is rather hilly, and for this reason it is very unfavorable for torsion balance work. In order to secure usable results the stations were very carefully chosen. Where it was possible they were located in the narrow valleys. Where this could not be done they were placed on the top of gentle hills. Minute terrain and topographical corrections were made on every station for the observed gradient value. (Curvature measurements were not attempted because of the much greater corrections which would be required.) Levelling was made to a distance of 100 m. and topographical corrections were calculated mostly to 1000 m. using the contours of the 1:25,000 scale military maps. It was observed that most of the stations located in valleys with fluvial deposits gave erratic gradient values, unless the station was located near the center of the valley. The disturbing effect is evidently due to the density difference between the relatively loose recent sedimentation and the more compact material of the base of the valley. This effect could not be eliminated by the terrain correction. By appearance these valleys look favorable for torsion balance stations as they offer smooth, even areas for the locations. However, the smooth-surfaced recent fluvial deposits veil the uneven original erosional surface, and make it impossible to take it into con-

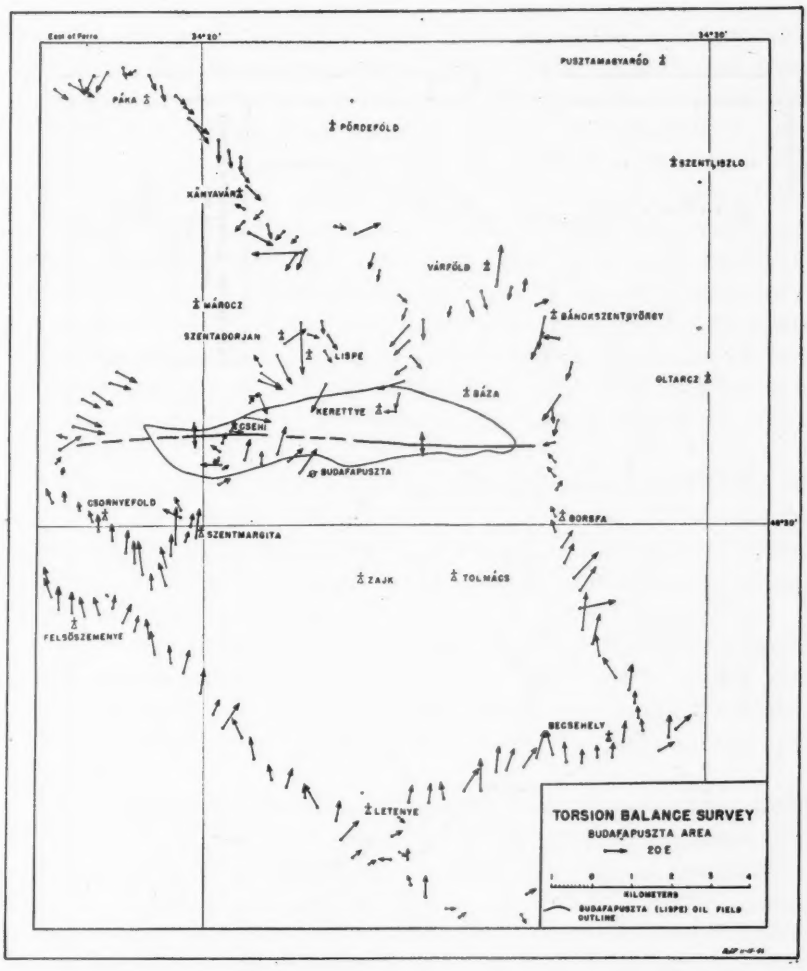


FIG. 3. Torsion balance gradients in the Budafapuszta area.

sideration when calculating the terrain corrections. The valleys subject to recent erosion have rather irregular topography, but if a relatively smooth place could be found for setting up the torsion balances the results were usually satisfactory, as the gravity effect of the terrain undulations could be computed and the results could be corrected. For the same reason stations on gentle hilltops, where loess was absent, also gave fairly good results. For density values average densi-

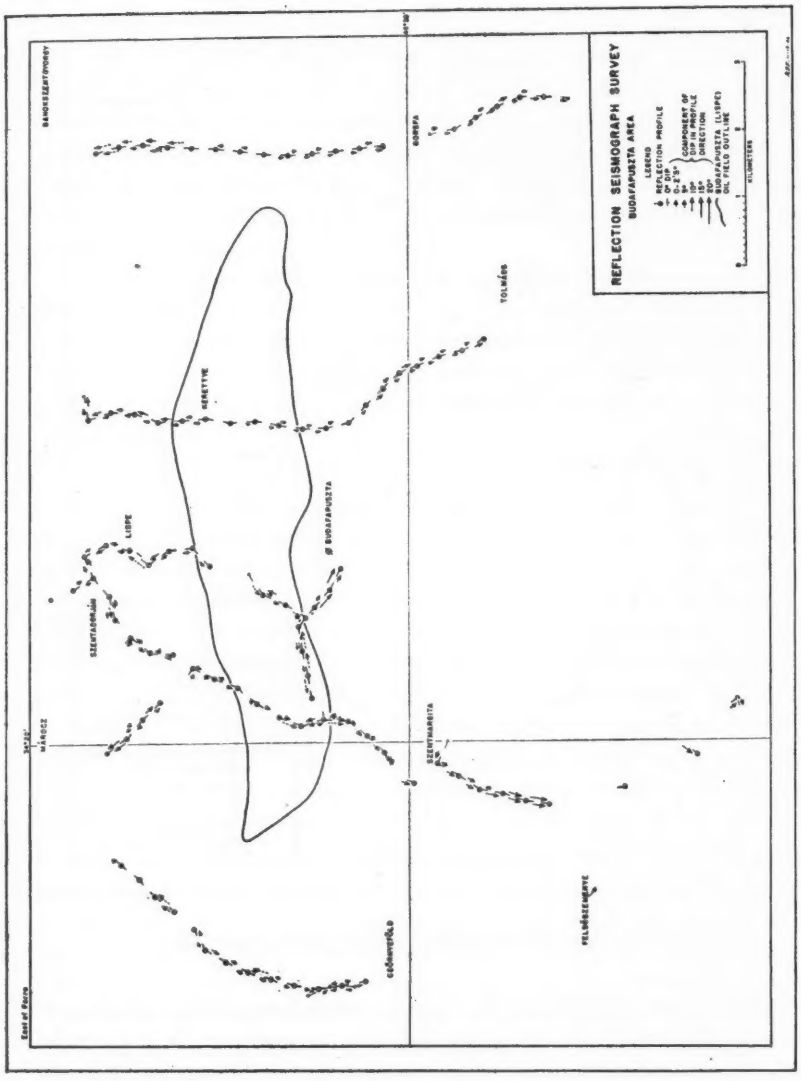


FIG. 4. Results of dip shooting in the Budafapuszta area.

ties of numerous samples were used. It was found that a better result can be reached using an average density value for a certain area, than by determining the density individually for each torsion balance station. The curvature values were omitted as—especially in the narrow valleys—the corrections were not accurate enough to obtain usable results. Fig. 3 shows the gradient values at 186 stations obtained in the Budafapuszta area. Although there are a number of erratic gradients, the north and south flanks of a major east-west striking anticline are clearly indicated. It can be seen that the gravity axis is about one kilometer north of the dry well drilled by the Hungarian Oil Syndicate. This indicated that the well was not on the top of the structure, but on the south flank. Actually this well is 600 meters down dip from the margin of the producing area as determined by drilling.

The gradients at, and north of Borsfa show an eastward dip on the structure and the gradients north of Csornyefold show a definite westward dip, indicating a dome on the crest of the main anticline. The adjacent synclines of the Budafapuszta anticline are south of Letenye and north of Paka.

The torsion balance survey of the Budafapuszta area was made in the summer of 1934. Based on these data a test was recommended 1500 m. northeast on the well drilled by the Hungarian Oil Syndicate. (As can be seen in Fig. 7, this is near the center of the oil producing area.)

It may be interesting to note that at the same time that the survey shown on Fig. 3 was made the area east and west of Budafapuszta was also investigated by the torsion balance and about 500 stations were completed in this territory. Total cost of the survey was about 11,000 Pengo (equal to $2000). It is believed that this is the cheapest and most efficient survey ever made as the 500 torsion balance stations contoured three domes on a main anticline each of which is now a proven oil field (Budafapuszta, Lovaszi, and Ujfalu). Cost of the survey per oil field was less than $700.

In addition to the torsion balance survey a reflection seismograph survey was made in the Buadfapuszta area during the winter 1935–36. As the crew was free only in the winter time, the work was extremely handicapped by weather and road conditions. Dip shooting was used with a spread of 240 m. (60–300 m.). The shotpoints were located practically along the same roads as the torsion balance stations. The results obtained are shown on Fig. 4. The dips determined from the

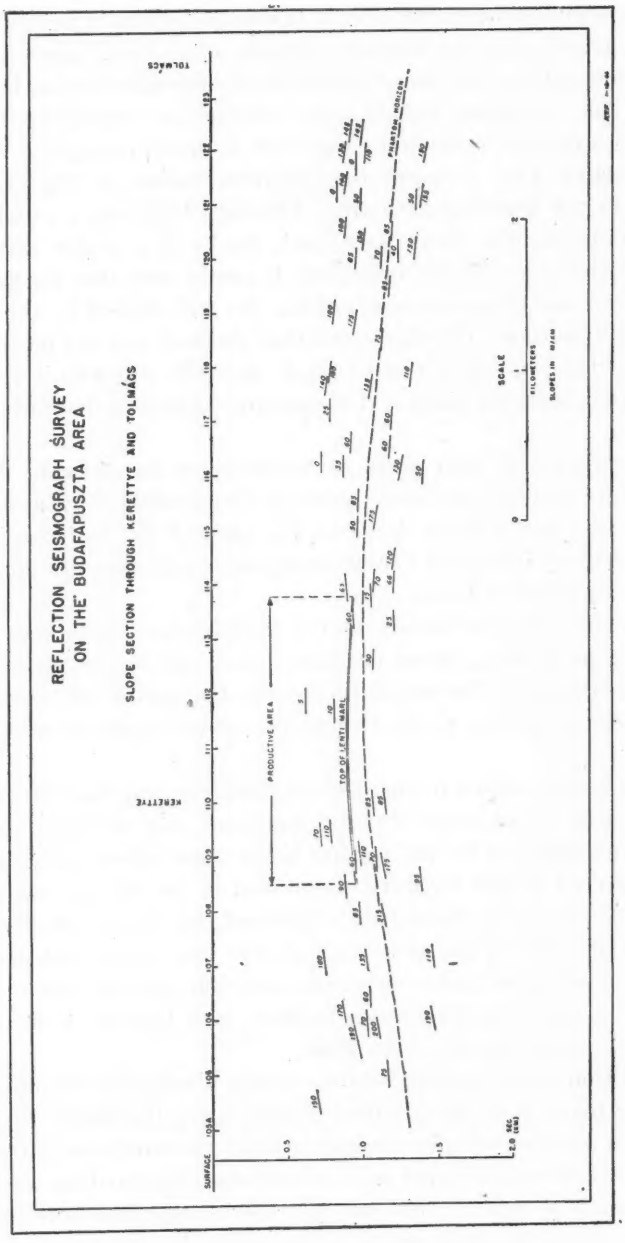


FIG. 5. Section showing dips in meters per kilometer, computed from seismograph records.

reflections are generally in accordance with the torsion balance data. They indicate clearly the north and south flanks of the east-west striking anticline. However, the axis of the structure could not be determined accurately as reflections along the crest of the anticline were rather poor. Still, as far as it can be judged from the rather uncertain results, it appears that the seismic axis is somewhat north of the gravity axis. A seismograph dip section is also submitted (Fig. 5) showing the observed dips and a "phantom" horizon which is thought to characterize the cross section of the structure.

Based on the torsion balance and seismograph data a test well was located on the Budafapuszta structure about 1.8 km. (5900 ft.) north of the Hungarian Oil Syndicate well. When choosing this location, road and transport conditions had to be considered also. Drilling started in July 1936 and was completed in March 1937. The drill encountered Upper and Lower Pannonian (Pontian), Sarmatian and Tortonian strata. The well yielded more than 10 million cu. ft. wet gas daily and some light oil from a depth of 3500 feet. At a latter date, when the gas of the well was used as fuel, the well yielded about 150 barrels oil daily.

Due to the technical difficulties lower strata could not be tested. Well No. 2 was drilled southeast of the above mentioned and produced about 300 barrels of oil daily from a lower sand.

In 1937, after the first well at Budafapuszta was completed, a gravity meter was available for the Eurogasco, and in the second half of 1937 a gravity meter survey was made in this area. The results of the survey are shown in Fig. 6. This map showing lines of equal gravity gives a clear picture of the Budafapuszta structure. Definite closure may be observed to the east and west defining a dome on the crest of the main anticline. Essentially the gravity meter survey shows a close correspondence with the torsion balance survey. Naturally, it is affected much less by the topography than is the torsion balance survey. The gravity meter map proved to be a reliable guide when developing the oil field by further drilling. It should be mentioned here that the gravity anomalies in the Transdanubian area in general correlate remarkably well with geological structure. The factors which favor this correlation are: (1) a large and progressive increase in density of the sediments from the surface to the pre-Tertiary basement; (2) absence of any sudden lateral density variation in the sediments; (3) absence of pronounced regional effects.

To the end of 1940 51 producing wells were drilled in the Budafa-

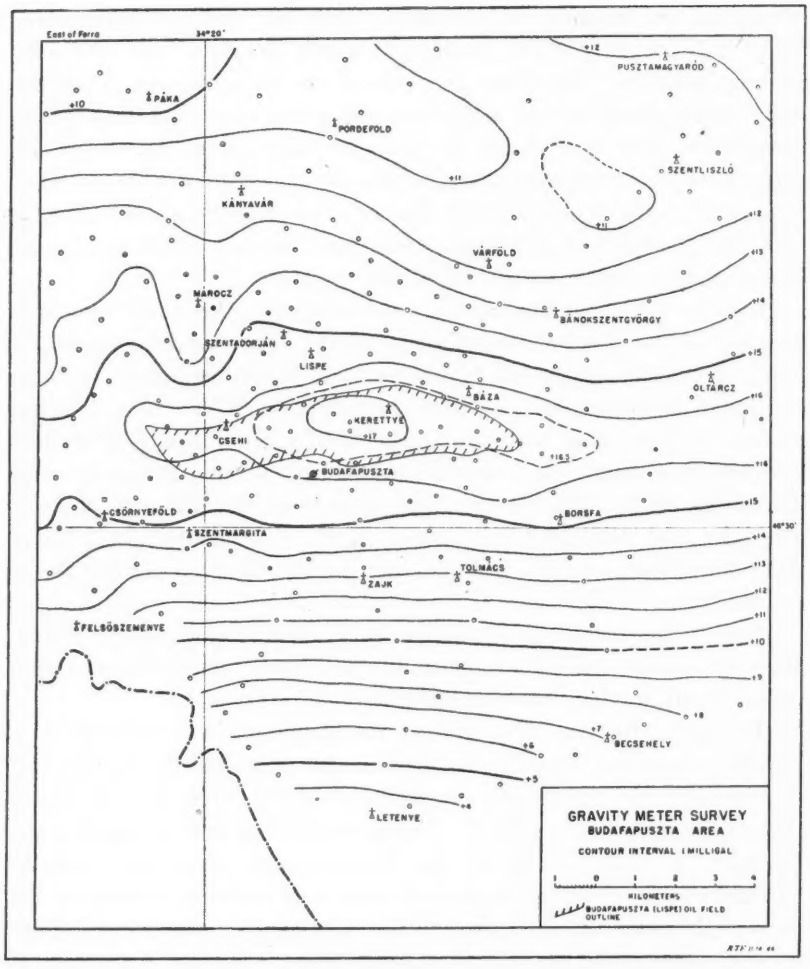


FIG. 6. Gravity meter map of Budafapuszta area.

puszta (Lispe) area and the total production for 1940 was 1,914,550 barrels of oil, produced from a number of sands in the Lower Pannonian. Based on the well data, the structure of the top of the dome was determined by subsurface contours drawn on a rather reliable marl bed, as shown by Fig. 7. The gas-oil boundary and that of the edge water are also shown.

The boundary of the producing area is shown on Figs. 1, 2, 3, 4, and 6 also, in order to facilitate orientation, and comparison of the

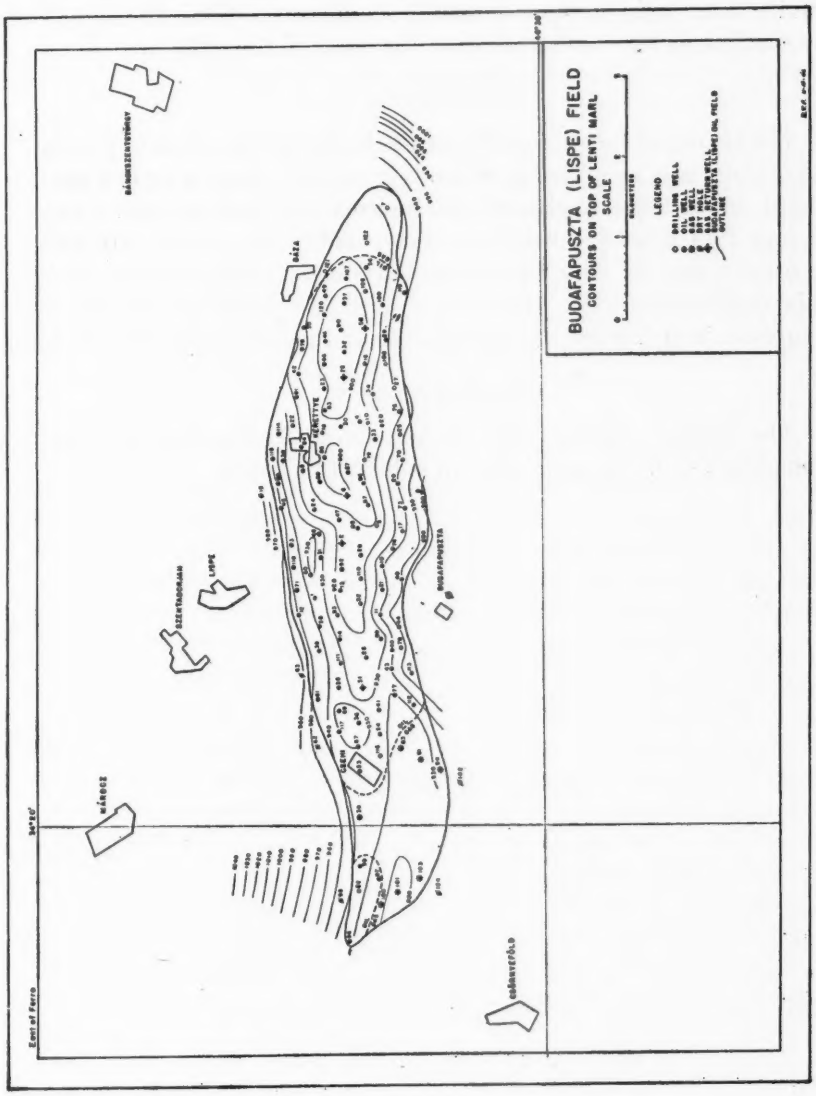


FIG. 7. Subsurface map of the Budafapuszta field.

various maps. The producing area occupies only the crest of what must be a very large structure. The width of the anticline, based upon the gravity data, must be approximately 18 kilometers from the axis of the syncline on the south to that on the north of the structure.

CONCLUSIONS

The history of the exploration of the Budafapuszta oil field proves the usefulness of geophysical methods in an area where a surface geological survey failed to give reliable information. Furthermore, it can be seen that a torsion balance survey made with proper care and expertness may be very efficient and economical even in areas with unfavorable topography. However, in hilly country the gravity meter is superior in giving detailed information on the subsurface structures.

ACKNOWLEDGEMENT

The authors express their indebtedness to the Standard Oil Company (N. J.) for permission to publish this paper.

VERTICAL VELOCITIES FROM REFLECTION SHOOTING*

L. W. GARDNER†

ABSTRACT

Reflection seismograph observations supply a means of determining the average vertical velocity of seismic waves from the ground surface to the depth of any good reflecting horizon, through measurements of "angularity corrections." Specially grouped arrangements of shot points and detectors are illustrated and described, which minimize error in making these measurements. Reflection seismograph observations using these arrangements were made at four locations where well velocity surveys were available. Comparison of results indicates that average vertical velocities good to within 3% can be obtained by this method, under favorable conditions.

The problem of assigning suitable vertical velocities in making interpretations of either reflection or refraction seismograph data is of generally recognized importance. Numerous attacks have been made on this problem, both theoretical and experimental. The most reliable information continues to be that supplied by well velocity surveys, but often they are non-existent, not deep enough, or too few in number to supply all the information desired in any given area.

The well known T^2-D^2 method is a reflection seismograph procedure, which, in principle, permits obtaining additional or supplementary vertical velocity measurements, when good reflections associated with particular reflecting horizons can be recorded and identified for both long and short spreads. However, in use, this method is apt to yield results which are quite inaccurate unless certain conditions are met, or unless a relatively large number of experimental tests are made and results averaged. It is the purpose of this paper to show that if certain specified conditions are met, fairly accurate results can be obtained, with comparatively few experimental tests.

For the arrangement of shots and detectors shown in Fig. 1, the equation

$$\overline{V}^2 = (X^2 - x^2) \cos^2 \alpha / (t_L - t_S)(t_L + t_S) \qquad (1)$$

is valid, under the assumption of straight line wave paths. In this equation,

$\overline{V}$ is the average vertical velocity to the reflecting horizon,

* Read at the Chicago and Houston meetings of the Society, 1946.

† Gulf Research & Development Company, Pittsburgh, Pa.

X and x are long and short distances, respectively, between shot points and detector positions,

t_L and t_S are the associated reflection times, corrected to a horizontal reference plane at the average level of shots and detectors, and

α is the dip of the reflecting horizon at the reflection point.

Equation (1) is obtained by expressing separately the lengths of the two wave paths $\overline{V}t_L$ and $\overline{V}t_S$ in terms of the common center point

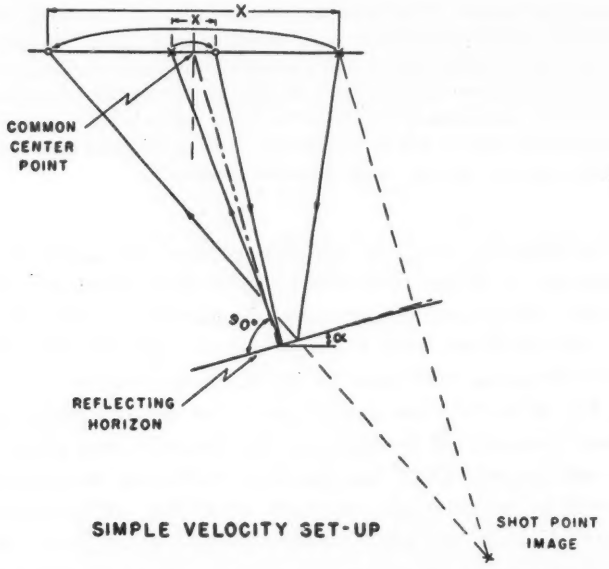


FIG. 1. Simple velocity set-up, illustrating principle of determining vertical velocity from observed reflection times, t_L and t_S.

perpendicular p, X, x, and cos α, using the Law of Cosines. Then p is eliminated between the two equations.

It is easily possible to make fairly precise measurements of the factors (X^2-x^2), $\cos^2\alpha$, and (t_L+t_S). However, it is difficult to obtain satisfactorily precise measurements of the factor (t_L-t_S). This difficulty is the principal reason why determinations of vertical velocities often are quite inaccurate. In order to improve the accuracy of velocity determinations, it is necessary to improve the accuracy of determinations of the factor (t_L-t_S).

This factor is the difference in angularity corrections for long and short setups. To minimize percentage error in its determinations, it is

important to work with clearly identifiable and correlative reflections, and also to make the value of $(t_L - t_S)$ as large as possible by using very long setups together with short ones. In practice, there are limits to the length of setups which can be used because, for very great lengths, reflections lose their identity and correlative character. It is rarely possible to make the factor $(t_L - t_S)$ greater than 0.10 sec. in magnitude. Frequently under the most favorable conditions possible, its value will be of the order of 0.025 sec. For this case, an error in measure-

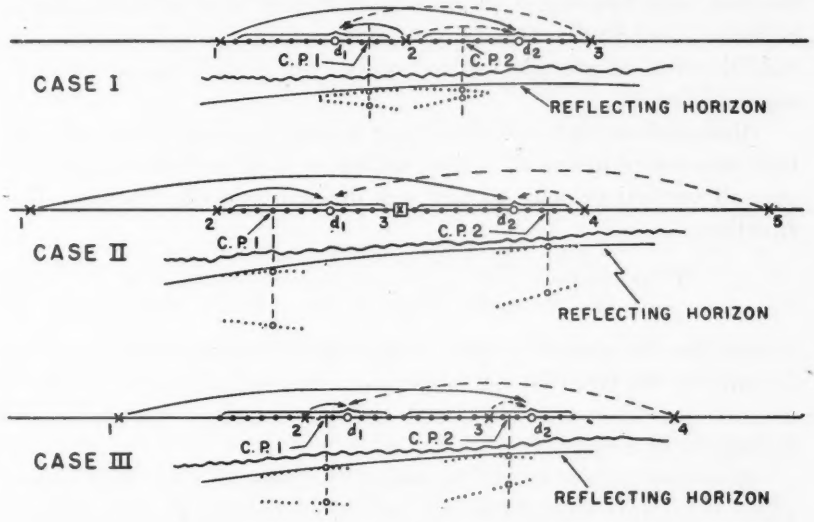


FIG. 2. Spread arrangements and plots of reflection times vs. center point positions, for which a common detector receives for a long and a short setup, and each long setup has a common center point with a short setup.

ment of 0.002 sec. would be an 8% error, which would cause a 4% error in the determination of $\overline{V}$. Accordingly, measurements of angularity correction differences must be good to about 0.002 sec.

To minimize error in measurement of angularity correction differences, special setups can be used which make use of two long spreads and two short spreads, so arranged that a *common detector receives for a long and a short setup*, and *each long setup will have a common center point with a short setup*. The first condition causes cancellation of near surface or weathering corrections in the factor $(t_L - t_S)$. The second condition is necessary to the validity of equation (1), unless the reflecting horizon is plane and level.

Fig. 2 illustrates three different arrangements of shots and detectors, cases I, II, and III, which satisfy the postulated conditions. The pairs of shots represented by the solid arrows conform with the condition of having a common center point. The pairs of shots represented by the dashed arrows also conform with this condition. Further, each detector "d_1" and "d_2" receives a long and a short shot. For all cases, the conditions require that shot point spacing shall be uniform, and that the space between detectors d_1 and d_2 shall equal the shot point spacing. A suitable magnitude of shot point spacing is between $\frac{1}{4}$ and $\frac{1}{2}$ mile. Small displacements from the uniform spacing conditions, of magnitude 100 to 200 ft., will usually introduce only negligible error.

Observational data obtained from a velocity setup using only the two detector positions d_1 and d_2 suffice to yield a determination of over-all vertical velocity to any well defined reflecting horizon. The equation

$$\overline{V}^2 = \frac{(X_1^2 - x_1^2)\cos^2\alpha_1 + (X_2^2 - x_2^2)\cos^2\alpha_2}{(t_{1L} - t_{2S})(t_{1L} + t_{2S}) + (t_{2L} - t_{1S})(t_{2L} + t_{1S})} \qquad (2)$$

is used for this determination. This equation differs from equation (1) only by the fact that the numerator and denominator are summations of quantities associated with the two center points, designated by subscripts 1 and 2.

Equation (2) is obtained by noting that equation (1) with appropriate subscripts applies for each pair of shots (Fig. 2) which have a common center point. This yields two equations of the form of equation (1), for each case illustrated. These equations are added, after transposition of the denominators to the left sides of the equations, and equation (2) follows.

It is convenient to make observations simultaneously with a multiplicity of detectors, disposed between shot points in an ordinary reflection spread arrangement. This aids in making proper correlations and furnishes a multiplicity of velocity determinations which can be averaged to furnish a more accurate result. Further, the consistency of the multiple determinations furnishes a check on the degree of their reliability.

It is evident from Fig. 2 that the shooting necessary for the velocity setup consists of the superposition of two *specific* long spreads on ordinary continuous reflection profiling. Cases I and II each yield a symmetrical arrangement when used for detector spreads located

between shot points. Also, these two cases used together supply a selection of longest useful line lengths, and furnish mutually supplementary data which are useful in establishing proper correlations. Case III yields a symmetrical arrangement when used with split spreads. As compared with ordinary T^2-d^2 methods, emphasis is placed upon the use of particular long spreads in relation to particular short spreads whereby weathering corrections cancel under detectors, and substantial coincidence of center-points minimizes error due to dip or curvature of the reflecting horizon.

It has been assumed that wave paths are straight lines in the derivation of formulae (1) and (2). Actually, they are bent due to the presence of different formations contrasting in speed. Because of this fact, results will ordinarily be 1 to 3% too high. A reduction of the final result by about 2% usually will quite satisfactorily account for this factor.

In reading reflection times, a peak or a trough ordinarily is read. A "phase correction" for this fact is considered to be constant and cancels in the terms (t_L-t_S), but needs to be applied in the terms (t_L+t_S).

After selecting correlative good reflections for use, it is helpful to plot observed reflection times vs. center point positions as a check on the propriety of selection. This plot should show a distribution of points similar to that illustrated at the bottom of each of the three diagrams in Fig. 2. Computations from equation (2) can be simplified by taking into account the following considerations:

(A) If the shot point spacing is uniform and is represented by L, and if $\alpha_1=\alpha_2=\alpha$, it can easily be shown that, if N^2 is the numerator of equation (2), $N^2=4L^2\cos^2\alpha$, $12L^2\cos^2\alpha$, and $8L^2\cos^2\alpha$, respectively for cases I, II, and III. These relations are obtained, if the different distances in the numerator are expressed in terms of L and x_1. The value of the numerator is independent of the position within spreads of any paired detectors d_1 and d_2. It follows that the method is applicable to the use of grouped detectors as well as for single detectors.

(B) If there are deviations from uniformity of the spacing conditions, but the detector spreads are alike and contain a uniform distribution of detectors, computation of the numerator of equation (2) for the central position of the two spreads alone is necessary. Use of this value for other paired detector positions introduces only small error, and this error can be shown to cancel in averaging results for all paired detector positions within the spreads.

(C) It is possible to evaluate the terms of the denominator of equation (2) directly from observed times as follows: In the time difference terms, only corrections for shot hole elevations and weathering under shot holes need be applied, since elevation and weathering corrections under detector positions cancel. The corrections associated with the shot holes are common for all paired detector positions within the spreads. In the time sum terms, only a common approxi-

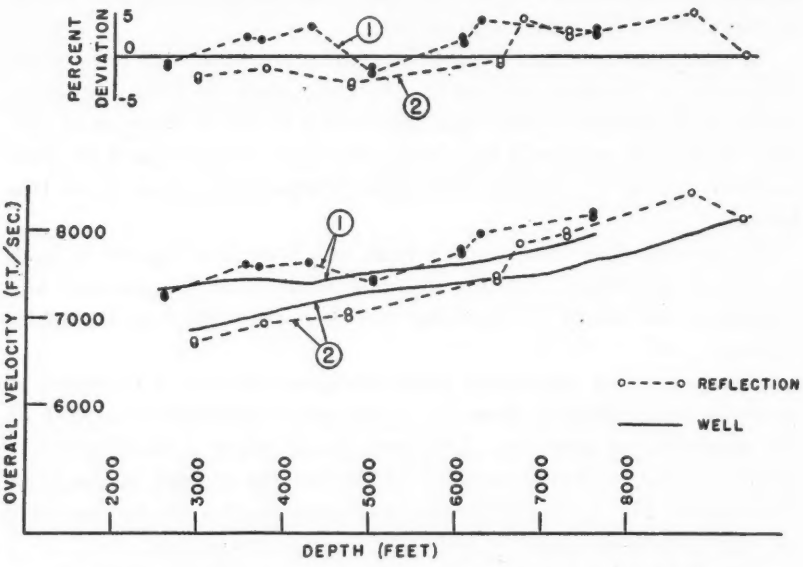


FIG. 3. Comparison between reflection and well velocity determinations for two locations.

mate value for weathering need be applied, since a small error in this correction will introduce only negligible percentage error. A common value for "phase correction" also needs to be applied in the time sum terms, if reflection peaks or troughs are read. To minimize possible error from an indeterminate variability of "phase correction" initial peaks or troughs on a wave form should be read. Because the velocity determination is measured downward from a reference level at the average level of all shots and detectors, there is substantial cancellation of elevation corrections within the time sum terms.

(D) The denominator of equation (2) must have a theoretically common value for all detector pairs, because the numerator does and $\overline{V}^2$ is a fixed value for any given reflection horizon being investigated.

Consequently, the use of an average value of the denominator for all paired detectors will give a good average value for $\overline{V}$.

Fig. 3 shows reflection velocity determinations compared with well velocity determinations in a low velocity area for two test cases, with velocity setups located across the deep tests. Velocity determinations are on a number of horizons. Double points represent separate determinations by different interpreters from the same record data. Percentage deviations of the reflection velocity determinations

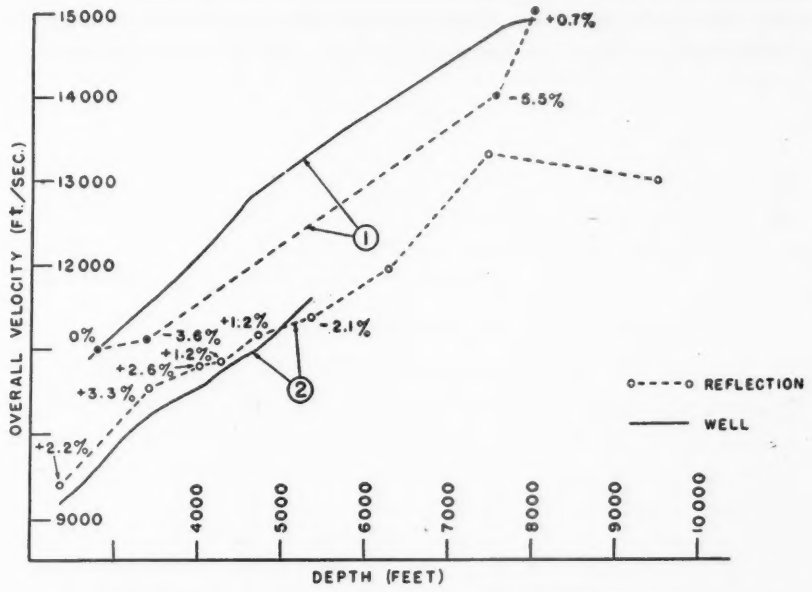


FIG. 4. Comparison between reflection and well velocity determinations for two locations.

from the well velocity determinations are shown on the upper curves. The majority of these deviations are within 3%. The few points representing larger deviations may be attributed to inferior quality reflections. The two test cases are separated by only about three miles but show a marked change in vertical velocity. It is interesting that the lateral change in velocity as determined from the reflection shooting agrees roughly with the lateral change in velocity established from the well shooting.

Fig. 4 shows reflection velocity determinations compared with well velocity determinations in a high velocity area for two more test

cases. Percentage deviations are represented by figures on the curves. These two tests are separated about thirty-five miles, and they show a marked change in vertical velocity. The reflection velocity determinations are sufficiently accurate to indicate the lateral change in velocity from one test to the other.

These examples suffice to prove the essential soundness of the method and to show that results good to within about 3% can be obtained. In practice, the most serious difficulty encountered is failure to obtain good correlative reflections on all of the four shots which make up a velocity setup. This difficulty often can be overcome by making setups where it is known that good reflections are obtainable.

GEOPHYSICAL CONTRIBUTIONS TO VIBRATION MEASUREMENTS AND MICRO-CHEMISTRY*

P. F. HAWLEY†

ABSTRACT

This paper gives a brief account of the development, during the war emergency, of equipment made especially for the measurement of vibration and strain in airplane structures in flight. Experience in the design and manufacture of seismograph equipment made rapid development possible. A mass spectrometer is also described. This instrument was built originally for analysis of gas samples in connection with geochemical prospecting, was then adapted for rapid analysis of complex hydrocarbon mixtures and has found application particularly in control of refinery processes.

New projects far afield from their previous activities have been undertaken by most geophysical laboratories during the past few years, providing material for unusual stories. This is a partial account of the activities of one such organization.

STRAIN AND VIBRATION MEASURING EQUIPMENT

The Consolidated Engineering Corporation had been engaged, up to 1939, entirely in research and manufacture of geophysical surveying equipment. At that time, representatives went to the newly formed National Defense Research Council to offer the services of the technical staff. It was found that the Air Corps was in urgent need of lightweight equipment to operate in military aircraft under the most severe maneuvering conditions, to record the relative velocity, strain, or acceleration of the aircraft structures. The problem required that strains and accelerations of opposite senses must be recorded as positive and negative deflections. After considerable discussion, it was decided to undertake this project.

Since this company had never made such equipment, it was necessary to start from the bottom—a procedure often found in geophysics. Fortunately, the basic principles involved are very similar to those in seismic reflection and refraction recording equipment.

Many of the problems involved, however, accentuated those normally found in seismic equipment. In flight testing, accurate repro-

* Read at the Chicago Meeting of the Society, April, 1946.

† Vice President in Charge of Engineering Design and Development—Consolidated Engineering Corporation, Pasadena, California.

duction of the *amplitudes* is of basic importance. It is customary to specify that the complete equipment, from pickup to oscillograph, will reproduce the amplitude of the variable for a wide temperature range (usually from −40° to 110°F.) with an over-all error not to exceed 5%. The total volume of the equipment must not exceed that of the "disposable" items in the military aircraft. It is not at all unusual on pursuit planes to mount the oscillograph in one empty gasoline drop tank, and the bank of amplifiers in a second drop tank, under the wings. Minimum space and weight are as indispensable as accurate aplitude reproduction.

A further complication is the fact that when recording either acceleration or strain, it is necessary to record static, as well as dynamic, quantities. Two systems were suggested: the use of a d-c amplifier, with all of its attendant difficulties, or (2) the use of the pickup in an audio-frequency Wheatstone bridge, whereby the bridge output is an alternating current signal, the steady state component of which corresponds to the static strain or acceleration. This can be amplified by a normal a-c amplifier. This carrier system was chosen. The main difficulty with this system arises in the demodulation, since it is necessary to have the polarity of the demodulated signal reverse when the bridge output reverses. The only indication of this bridge reversal is a 180° change in the signal phase. The demodulator therefore, must be phase sensitive. Incidentally, no variable volume control or expander can be used in the amplifier.

The recorder requirements vary from those of the geophysical oscillograph. The instrument must take an automatic record of fixed length, so that if the pilot "blacks out" in a loop or a pull out, the oscillograph will not keep running paper through until he releases the key. The accuracy of the timing lines on the record need not be as great as that in the geophysical instrument. It is usually desirable to have simultaneous viewing of the wave forms being recorded. A quick selection of at least 3 widely differing film speeds is practically essential. A remote control to operate the oscillograph is customarily provided. Means must be provided for calibrating the entire apparatus, both as to amplitude and frequency response. The normal shaking table of the geophysical research laboratory is scarcely adequate for the response of accelerometers, since they automatically take the second derivative of the table displacement. Accordingly, any slight irregularities in the motion of the calibrator table are doubly accentuated. On the other hand it is usually unnecessary to provide a calibrator which will apply other than a sine wave motion.

Stresses in the aircraft are of fundamental importance. Accordingly, on the first set of equipment which was ordered, it was necessary to supply pickups of the accelerometer type, i.e., with natural frequencies considerably higher than those to be recorded. The pickups necessarily must be light-weight, should be magnetically damped if possible, and have a per cent damping of the order of 60 to 70%, to give maximum flat frequency response. The first accelerometers ordered were to be magnetically damped, with a response from 0 to 35 cycles. They were required to be linear with acceleration to at least 15 G, and to be usable at any orientation.

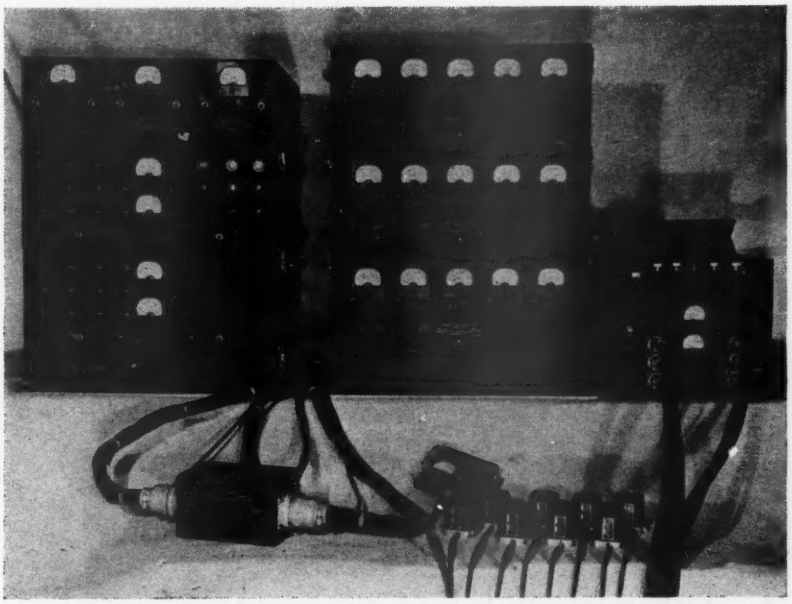


FIG. 1. Complete 12-channel flight test vibration recording equipment. Records acceleration, velocity, or displacement.

The first complete set of equipment is shown in Fig. 1. Eight accelerometers are shown in the lower right, although a maximum of 24 could be utilized, in groups of 12. These are connected to the two banks of a-c Wheatstone bridges at the left. Above these are the three power supplies required to supply the 1000-cycle oscillators, the bridges, and the three banks of 4-channel amplifiers shown in the center. These amplifiers connect to the recording oscillograph at the

right. A compact remote control is shown behind the accelerometers. Since 12 accelerometers or strain gages could be recorded at a time, a selector switch (to left of accelerometers) was provided to switch either bridge to the amplifiers.

The amplifiers can be used to record either the accelerometer output directly, or singly or doubly integrate this output, producing a velocity or displacement response.

The calibrator furnished is shown in Fig. 2. This is a reciprocating

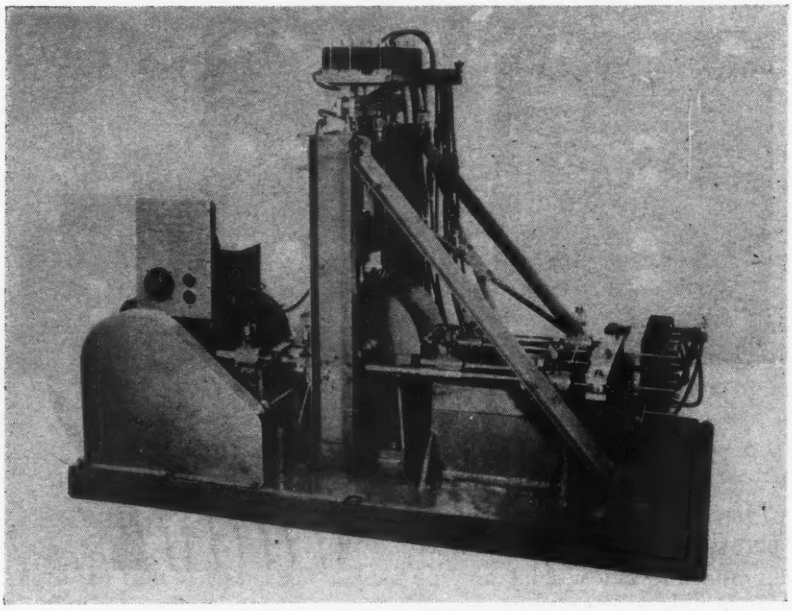


FIG. 2. Accelerometer calibrator, producing horizontal and vertical sinusoidal notion.

unit, producing a sinusoidal motion on a vertical and a horizontal table, adjustable from 0.001 inch to 2 inches double amplitude for frequencies from 2 to 50 cycles per second, at a load of up to 24 pounds total. The motion has very low harmonic content, which makes it extremely advantageous for accelerometer calibration.

Shortly after work had commenced on this order, this company took over the vibration recording equipment developed by the Sperry Gyroscope Company. This included small velocity pickups with low (10–20 cps) resonant frequencies, amplifiers and recorders.

Rapidly, the demands of the Air Corps, engine and automobile manufacturers have stiffened the early requirements. Many sets of equipment have been furnished which require recording acceleration or strain, but which are immediately adaptable at the flip of a switch to recording the response of the velocity pickups either directly or with single integration. At the present time, equipment is in process of manufacture that will record accelerations or strains, flat to 500 cycles,

FIG. 3. Velocity type pickup.

with approximately 3 times the gain of the early equipment, and occupying something less than one-fifth the space. Other equipment has a carrier frequency of 10,000 cycles, with a flat frequency response to 1000 cps.

A recently developed velocity type pickup is shown in Fig. 3. This has a flat frequency response from a minimum of approximately 7 cps to an undetermined maximum. It has been measured to 700 cps using a dynamic-type shaking table.[1] One interesting point about this

[1] Washburn H. & Olesen, R., "Transient Testing of Seismic Recording Apparatus," GEOPHYSICS, vol. 5, no. 4, Oct. 1940.

particular pickup is that the vibrating system fits closely the cylindrical opening in which it is placed, thus adding inertia mass of the fluid to that of the suspended system, markedly reducing the natural frequency without commensurately increasing the static sag of this system. The sensitivity of this pickup is approximately 0.11 volt per inch per second.

Another interesting development of this organization has been the

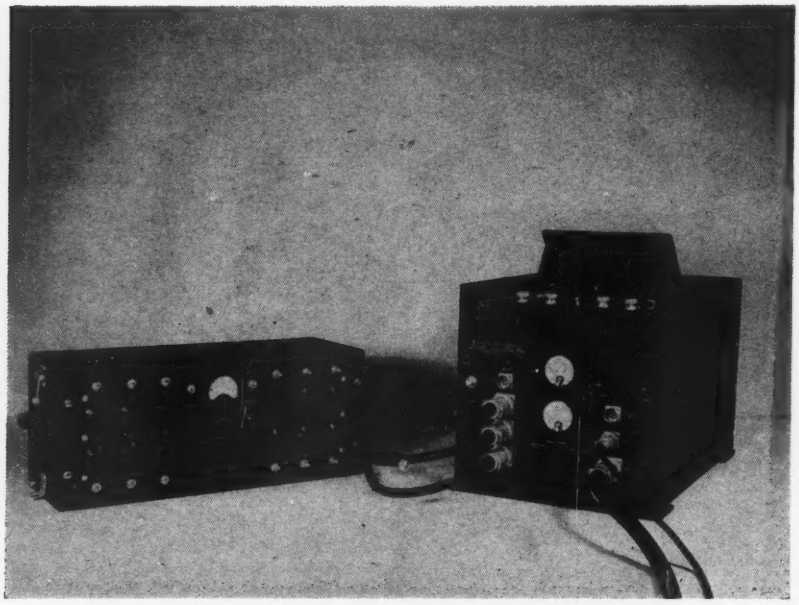


FIG. 4. Direct recording 12-channel strain gage unit for flight test involving only bridge balance and oscillograph.

production of extremely sensitive recording galvanometers. This has permitted the elimination, in many cases, of amplifying equipment in the recording of strain gage output, always notoriously low in output voltage. The most sensitive of the galvanometers employed has a recording sensitivity of the order of 1″ for approximately 14 μa. With this galvanometer in the recording oscillograph all that must be provided for recording is a bridge balance for each channel. Such equipment is shown in Fig. 4.

One important outcome of this type of development has been the general acceptance of such equipment for the quantitative study

of vibration characteristics of widely different types of rotating machinery, vibrating structures, and transportation equipment.

MASS SPECTROMETER DEVELOPMENT

Another development, which also has played an important wartime and peacetime role, again originated in a geophysical (or geochemical) application. The difficult problem of determining micro-concentrations of light hydrocarbons, arose a few years before the war because of the pressing interest in soil gas analysis. It was known that qualitative determinations of small concentrations of hydrocarbons could be made by the mass spectrometer, by a process of ionizing the gas, passing it through combined electrostatic and electromagnetic fields which sorted out ions according to the relation of their charge to mass, and counting the number of ions reaching a collector. Whether such an instrument could be built to give *quantitative* determinations, and whether one hydrocarbon could be determined in the presence of others remained to be demonstrated. A period of very intensive investigation, which involved the construction of two different mass spectrometers, was commenced by Dr. Washburn and his research group early in 1939. The number of obstacles which were overcome resembled both in quantity and quality those opposing the early users of the reflection seismograph. By the end of 1939, Hoover and Washburn presented results before the AIMME[2] showing that quantitative determinations of small concentrations of gaseous hydrocarbons in a mixture could be determined with an error of less than 10%.

It was found that there was very definite interest in the use of this instrument, by the major oil refineries, for light gas analysis. Accordingly, an instrument was developed to meet these requirements. Considerable thought was given to making it as automatic and foolproof as possible. At the same time, the accuracy of the instrument was improved to such a point that when samples were sent in for analysis, before the purchase of the first instrument, it was possible to determine accurately and rapidly not only the concentrations of the constituents deliberately placed in the sample container, but also the fact that the sample container had been washed with acetone in the cleaning process before the sample was admitted.

The first instrument was delivered to the Atlantic Refining Com-

[2] Hoover, H. & Washburn, H., "A Preliminary Report on the Application of the Mass Spectrometer to Problems in the Petroleum Industry," *Petroleum Technology*, May 1940.

pany in 1943, It is illustrated in Fig. 5. At the left side is the glass apparatus used to introduce either gaseous or liquid samples, and to supply calibration mixtures as required. The actual spectrometer unit is located just to the right of this apparatus, the tube in which the analysis takes place being visible between the electromagnet coils. The control and recording cabinet is directly in front of the observer.

FIG. 5. First commercial mass spectrometer.

The mass spectra are recorded oscillographically on the instrument just above the observer's head. The d-c amplifier and its controls are located just below. The precision controls for the electric and magnetic fields are located to the right. The meters directly in the middle indicate the conditions in the ionization chamber and tube.

After the sample is introduced, it is merely necessary to push a button to record the spectrum. This requires not over 5 minutes. The average time per sample on a long-time routine basis, including calibration, supervision, maintenance, etc., runs approximately 20 to 30 minutes for 10 to 12 component mixtures. The time taken to analyze the data is about three times as long, since it is necessary to solve as many simultaneous equations as there are constituents. However, this

gross figure of 1½ hours is still not over a fifth of the time required for the best analytical procedure previously available. At the same time, the errors are reduced to a few tenths of one per cent. This is about ten times as good as normally obtainable with prior methods.

It was undesirable to have such a high ratio of computing time to instrument time in the use of this mass spectrometer. A 12-simultaneous-equation electrical computer has been developed. This instrument is shown in Fig. 6. It shortens the computing time approximately two-thirds. The errors in computation are usually under three parts in the fourth place.

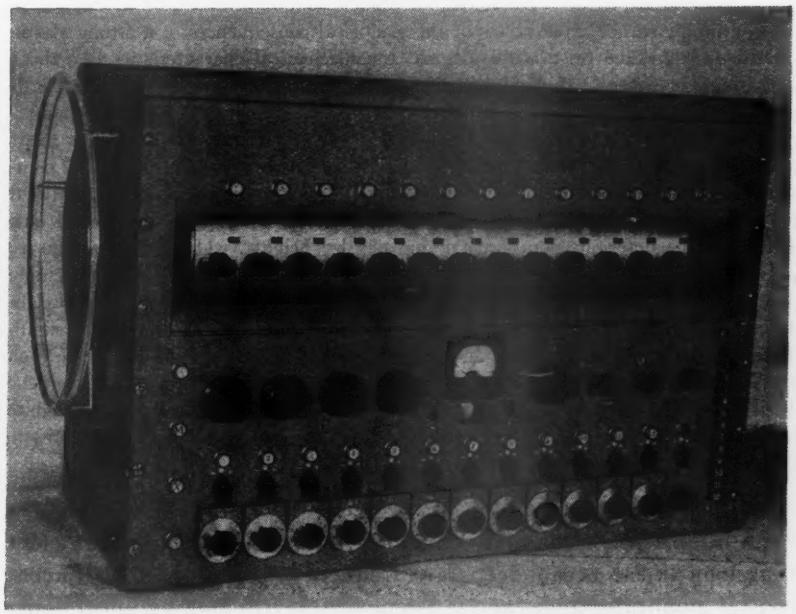


FIG. 6. Electric computer, for solving up to 12 linear simultaneous equations.

It is not unusual for new industrial equipment to evolve from solution of problems in a different field. Although this is true of both the vibration and strain equipment and the mass spectrometer, it was felt that these would be of particular interest to this Society, since they are among the few illustrations of this evolution coming from the geophysical field, and since their development was greatly accelerated by the knowledge of geophysical instrument principles possessed by the members of the laboratory.

QUANTITATIVE ASPECTS OF JUXTAPOSED OCEAN DEEPS, MOUNTAIN CHAINS AND VOLCANIC RANGES

ROSS GUNN*

ABSTRACT

Continuing earlier explorations of the geological consequences of a strong elastic lithosphere supported on a weak magma, the mechanical characteristics of a shear thrust fault are examined. Due principally to the differential cooling of the continental and oceanic areas and the higher standing of the former, continental boundaries are regions of potential weakness and the lithosphere there is subject to shear failure with resultant over-thrusting of the continental sector when sufficiently compressed by horizontal forces. The deformations of such a compressed and fractured lithosphere and the fibre stress distribution therein are quantitatively worked out, permitting the determination of maximum depths, heights, widths, figures, gravity anomalies, and fibre stresses. These estimated quantities are found to be strikingly similar to the properties of a geological area on the western coast of Mexico that exhibits juxtaposed ocean deeps, mountain and volcanic chains. The reasons for the simultaneous existence of these remarkable earth features and their special relation to each other are shown to follow immediately from the mechanical characteristics of the lithosphere. The existence of volcanic activity only in regions where there is a definite tendency for the *bottom* of the lithosphere to be in *tension* gives a valuable clue as to the basic mechanisms responsible for volcanic activity.

A number of writers have drawn attention to the important fact that long linear ocean deeps are frequently paralleled by adjacent coastal mountain ranges and, at some distance inland, by linear zones of volcanic activity. This striking geometric arrangement is observed in a number of places on the earth, notably south of Java and on the western slopes of Mexico. Vening Meinesz[1] has noted that "In the West Indies, as well as the East Indies, volcanoes occur in bands parallel to the [gravity] anomaly-strip at a distance of about 150 kilometers and especially at the inside of curved parts of the strip." Recently W. H. Hobbs[2] drew attention to a remarkable area on the western slope of Mexico saying "Today a range is rising parallel to the Pacific Ocean and five known new volcanoes are ranged at its

* Naval Research Laboratory, Now Director Physical Research for U. S. Weather Bureau, Washington, D. C.

[1] F. A. Vening Meinesz, Report Commission on Continental and Oceanic Structure, Washington 1937, p. 37.

[2] W. H. Hobbs, Science, 99, 287, April 14, 1944.

back in line with many others, all of them young and mostly active. Offshore from the rising ridge at distances varying from 70 to 100 miles there extends a deep trough which is steeper toward the land and with depths of from 3000 to 3500 fathoms. Between the line of active young volcanoes and the coast is a mountain range, the Sierra Madre del Sur. Its seaward slope is steep and marked by wave cut terraces, a "coastal staircase," bearing witness to the fact that the land has here lately risen . . . to its present altitude."

The recurrence of such parallel distributions of unusual linear features over the face of the earth implies that there is a common relationship between them. It is important to discover this relationship, if it is real, because it will inevitably shed light on the structure of the earth and help guide geological interpretation. The justification for theoretical study is to be found in the necessity of obtaining a simple framework of geological understanding that is quantitatively satisfactory before attempts are made to give a more detailed description. It is the province of the field geologist to fill in these complex interrelations and about all the geological physicist can do is to outline the basic mechanisms and trends and express them in specific numerical terms. The evidence presented in this paper suggests that the parallel distributions of mountains, deeps and volcanoes follow naturally from the properties of the lithosphere, if it is assumed to be strong, elastic and supported by an underlying weak magma. That the lithosphere has these special properties has been well established in a series of recently published quantitative investigations.[3]

It is important to examine various simple mechanical systems that can simultaneously reproduce all the outstanding features of parallel juxtaposed earth features. Such a mechanical description must be consistent with the known mechanical and elastic properties of

[3] Ross Gunn.

(a) A Quantitative Study of Mountain Building on an Unsymmetrical Earth, Jour. Franklin Institute, 224, 19–53 (1937).

(b) A Quantitative Evaluation of the Influence of the Lithosphere on the Anomalies of Gravity, Jour. Franklin Institute, 236, 47–65 (1943).

(c) A Quantitative Study of Isobaric Equilibrium and Gravity Anomalies in the Hawaiian Islands, Jour. Franklin Institute, 236, 373–390 (1943).

(d) A Quantitative Study of the Lithosphere and Gravity Anomalies along the Atlantic Coast, Jour. Franklin Institute, 237, 139–154 (1944).

(e) The Mechanics of the Lithosphere and its Relation to Gravity Anomalies and Fracture, Transactions, American Geophysical Union, Part IV of 1944, p. 633, March 1945.

the lithosphere, the anomalies of gravity and the general behavior of volcanoes. Because the problem is of such great importance, several possibilities were examined with sufficient quantitative care to compare them with observation. The present presentation is the simplest one consistent with all the known important facts. In order that the problem may be mathematically formulated in precise terms, it has been necessary to idealize somewhat the structure of deeps and mountains to make possible a detailed calculation of the expected effects. However, the basic mechanics has been carefully preserved and the results therefore should be useful in guiding future geological discussions and investigations.

Long linear earth features occupy a position of special interest in earth physics. The frequency and regularity of occurrence of such long linear earth features show that a definite method of formation is associated with their production. These earth features have a marked tendency to parallel continental boundaries or great oceanic arcs extending for thousands of kilometers. There are ample observational data to show that these features are usually formed at right angles to a systematic compression in the lithosphere. The exact origin of this horizontal compression can not yet be definitely established but its existence can hardly be doubted.

The principal suggestions that have been advanced for the generation of ocean deeps and having a reasonably adequate physical basis are:

A. Down-folding produced by horizontal compression and accompanied by a thickening of the sedimentary layers.[1]

B. Down-folding induced by forces derived from downward convective circulation of the underlying magma.[1]

C. Overthrusting and underthrusting at shear faults in the lithosphere.[4]

At first sight, down-folding by horizontal compression seems the most rational suggestion but, upon analysis, it is found that the assumption is not quantitatively satisfactory. By adopting approximately known values for the sectional moment of inertia of the lithosphere, calculations show that sufficient deformation of the earth's crust by horizontal compression during the present era cannot take place unless the modulus of elasticity of the crust is absurdly low or unless the horizontal compressive stress notably exceeds the compressive strength of the rocks comprising the crust.[3a] That is to say, the

[4] E. Suess, The Face of the Earth, Vol. 3.

elastic rigidity of the lithosphere is so great that any applied compressive stress of sufficient magnitude to produce a down-fold of the type proposed by Vening Meinsz will crumple the rock and produce a general area of plastic flow in which up-warping is just as probable as a down-warp. Such a mechanism could hardly form a typical deep displaying large negative gravity anomalies, although it might be related to mountain building. The dynamics of the compression appear to show clearly that the lithosphere will fail in shear before it will generally crumple producing a down-warp or an anticline.[3]

If adequate vertical forces are available to deform the lithosphere vertically, there is no doubt that crustal buckling of almost any conceivable magnitude is possible. Vening Meinesz suggests that the convective motion of the magma underlying the crust is sufficiently great and localized in nature to produce the observed down-warp.[1] The suggestion requires quantitative investigation before it can be seriously considered because the only type of continuing convective activity that can exist physically is the downward transfer of dense magma toward the center of the earth, with an accompanying replacement by a less dense magma. The concentration of density toward the center of the earth is already well advanced so that the resulting stratification acts as a powerful brake on convection and any circulation that now exists will be restricted to small cells. The geological forces due to permissible size cells do not appear to be of importance. It is difficult, too, to understand why the downward convective transport should occur only in cells having special long linear configurations. Convective activity having such a specialized geometry is never encountered in any ordinary fluid. It is conceivable but not probable that these difficulties may be removed by a detailed quantitative examination of the phenomena, but the hazards of adopting it at this time appear great.

SHEAR FAULTING AT A CONTINENTAL BOUNDARY

An investigation of the various possibilities enumerated above has led to the conclusion that shear faults and thrusts are the dominating mechanisms responsible for the production of long linear earth features. Suess[4] has considered the problem in relation to both mountain chains and deeps. The commonly observed folding of mountains shows that compressional stresses of great magnitude have been systematically applied at right angles to the direction of such mountain chains. A quantitative study of the mechanics of mountain

building on an elastic lithosphere supported on a weak magma show that in order to describe gravity anomalies near mountains, deeps, and continental borders, the lithosphere cannot be weak and subject to plastic deformation by moderate stresses even when these are applied for a long time, but must be strong and elastic.[3] It is found from these studies that the rigidity of the lithosphere is such as to distribute a localized load to a distance of some 200 kilometers before this load is finally passed on to the supporting asthenosphere.

With the application of horizontal stresses approximating 10^9 or 10^{10} dynes per square centimeter to such a strong and elastic lithosphere, shear failure along the line of maximum shear is not only mechanically possible but probable. It will, in fact, take place always at stresses less than those required to produce a down-fold, unless our present estimates of the elastic rigidity of the lithosphere are in error by orders of magnitude. With great compressional stresses existing over wide areas of the lithosphere, it is reasonable to expect that shear failure will not occur in a random manner but will occur at points of unusual stress, perhaps caused by some systematic deformation. For example, it may be noted that at a continental boundary the adjacent oceanic area has probably cooled and contracted more than the continental area. This differential contraction sets up localized stresses at the boundary of the continent that act much like a "notch" in a test specimen of steel to concentrate the impressed stresses and thus promote a mechanical failure more or less coincident with the area of localized stress or at the continental boundary.

The differential contraction of oceanic and continental areas has a further mechanical consequence. Because the continental areas stand above the adjacent ocean and because they are both subject to the same tangential compression, an overturning couple is produced resulting in a marked mechanical tendency for shear failure to proceed in such a way that the higher or continental area will override and depress the lower oceanic section. Perhaps this may not always happen, but the mechanical system of stress is such that overriding of the higher standing areas is more probable. Numerical values of the expected stresses due to the differential cooling of the continental and oceanic sectors may be estimated and they are found to be an appreciable fraction of typical horizontal compressive stresses. Further, it may be noted that many continental boundaries have been slowly acquiring great loads of sediment which will locally deform and stress this boundary area.[3d] Thus, for many reasons one may expect a tangentially compressed lithosphere to fail systematically at or near

a continental boundary, provided only that adequate horizontal stresses are available to propagate an initially small shear failure occurring at the surface. Attention is also drawn to the fact that most earthquakes represent some form of shear fracture and that the spatial distribution of earthquakes at various depths with respect to the coastline is sometimes such as to suggest a great shear fault extending throughout the surface layers.[3d] The weight of evidence, therefore, is consistent with the idea that a grossly compressed lithosphere will not be thrown into a downwarp but will normally fail in shear near the boundary of the continent in such a way that the continent will override the adjacent oceanic area. It will be shown in the following paragraphs that the mechanical evolution of such a shear fault leads to associated parallel earth features having properties remarkably like the observed parallel deeps, mountains and lines of volcanic activity.

THE MECHANICS OF A COMPRESSED SHEAR FAULT IN THE ELASTIC LITHOSPHERE

Earlier investigations of the deformation produced in a hydrostatically supported elastic crust by vertical loading and horizontal compression have emphasized the fact that great deformations were inevitably associated with lithospheric weakness and failure.[3] As in earlier papers, the upper few kilometers of the crust are ignored and one considers a section of the homogeneous elastic lithosphere of unit width that lies at right angles to and crosses a continental boundary. Let the x axis of a reference system coincide with the neutral axis of this long section, orient the y axis vertically and the z axis along the continental boundary. The origin near the shore line is assumed to coincide with the intersection of the shear fault with the earth's surface and nearly coincide with the concentrated stress zone due to differential thermal contraction and the higher standing of the continental sector. The length of the continental boundary along the z axis is assumed to be great enough so that the deformation of the selected section of unit width is typical of the whole region. Let the thickness of the section be T, its modulus of elasticity E, then I its section moment of inertia per unit width will be $T^3/12$. This section of the lithosphere may be considered to be a loaded beam resting on and supported by the underlying weak magma. Suppose that a horizontal compressional stress S is applied to the section along the x axis producing vertical (or y) deformations. Any vertical deformation $-y-$will displace the underlying supporting magma and this will

be resisted by a vertical counterstress of magnitude d_0gy where g is the acceleration due to gravity and d_0 is the density of the underlying displaced magma. Occasionally in geological structures a downward deformation of the crust induces the deposition of sediments or water of density d on top so that the net restoring stress in this case is $(d_0-d)gy$. Applying the well established laws of beams to the problem, it has been shown that the differential equation describing the figure and deformation of the selected equivalent beam or lithosphere is[3a]

$$EI\frac{d^4y}{dx^4}+ST\frac{d^2y}{dx^2}+(d_0-d)gy=0. \tag{1}$$

Imposing the boundary conditions at great distances from the application of any vertical force, it is found that the only important solution of the basic equation bearing directly on lithospheric problems is

$$y=P\epsilon^{-ax}\sin bx+Q\epsilon^{-ax}\cos bx \tag{2}$$

where P, Q, a and b are constants dependent upon boundary conditions and the properties of the lithosphere. Now Eq. (2) may be periodic or non-periodic in character. It has been emphasized[3a] that the non-periodic solution is geologically of the greatest importance unless present estimates of the modulus of elasticity or thickness of the lithosphere are greatly in error. This non-periodic solution describes the deformation just as long as the horizontal compressive stress S in the lithosphere is less than a critical value approximating 7×10^{10} dynes/cm^2. It may be remarked that there is little evidence to suggest that widely distributed stresses exceeding even 10^{10} dynes/cm^2 are encountered in the earth's crust because such stresses will crumple and cause to flow plastically almost any common rock.

The critical stress at which large-scale folding may be produced is approximately 7×10^{10} dynes/cm^2 and is given by

$$S=\sqrt{\frac{(d_0-d)gET}{3}}. \tag{3}$$

As long as the horizontal stress S is less than this critical value, the roots a and b in Eq. (2) are given by

$$a=\pm\sqrt{q^2-\frac{3S}{ET^2}} \tag{4}$$

$$b=\pm\sqrt{q^2+\frac{3S}{ET^2}} \tag{5}$$

where q is defined by

$$q^4 = \frac{3(d_0 - d)g}{ET^3}, \tag{6}$$

and has an average observed value of $q = 8.4 \cdot 10^{-8}$ cm^{-1}.[3b] Returning now to the selected section of the lithosphere that has been adopted for study, one is led to inquire what will happen to the beam as the horizontal stress is steadily increased from zero to the critical stress for folding the lithosphere or 7×10^{10} dynes/cm^2. The question is pertinent because when the earth was born the outer skin was without strength and it is logical to suppose that the strength and compressive stress in the lithosphere have both increased with age until today we see much evidence of horizontal compression sufficient to produce considerable surface deformation. As has been emphasized, it is not considered probable that appreciable crumpling of the lithosphere as a whole has taken place. Rather, because the strength in shear of most known rocks is less than their crushing strength, it is believed that as the horizontal stress is increased to the shear failure point, areas of localized stress due to other causes will initiate failure along a plane of maximum shear. This failure relieves the applied stress and it is only restored by severe overriding of the broken segments. Usually, the localized failure will propagate itself throughout the crust, permitting slight slippage and thus localized heat production. The heat produced along the slippage plane will raise its temperature and possibly cause the rock to flow plastically over the whole plane of failure. Too little is known about the strength of rocks at great depths to be certain that such is the exact mechanism of crustal failure, but since the processes of plastic flow are closely related to shear failure and these usually occur at lower stresses, it is believed that the process of shear failure is the controlling one.

Now if a shear failure is produced, it is clear that a continuing horizontal stress will produce over- and underriding and this in turn lifts or depresses the fractured ends of the lithosphere, producing tremendous vertical forces that are capable of grossly deforming the lithosphere. As the overrunning segments mount higher and higher, increased restoring stresses are produced that will ultimately establish equilibrium. In general, however, slight readjustments of position may have a large temporary effect in readjusting the impressed system of stresses. As has been shown[3a] the deformation of the lithosphere as a whole may be expressed in terms of the amount of over-

riding because the vertical forces produced at the shear fault can be readily expressed in terms of the horizontal force or stress. Thus, since the horizontal compressive force is ST, the vertical force F_v per unit width acting on the broken end of the section is

$$F_v = ST \cos \phi \sin \phi \tag{7}$$

where ϕ is the angle the shear plane makes with the direction of the compressive stress S.

If it is assumed that a shear failure has taken place in the lithosphere and that overriding has resulted, then neglecting frictional forces on the faces between the two moving sections, one may show that the deformed neutral axis of the semi-infinite section is described by a solution to Eq. (1) having the form of Eq. (2) or

$$y = \frac{12F_v\epsilon^{-qx} \cdot [(a^2 - b^2) \sin bx + 2ab \cos bx]}{ET^3b(a^2 + b^2)^2 - 12STb(a^2 + b^2)} \tag{8a}$$

or more approximately by

$$y = \frac{2F_vq\epsilon^{-qx} \cos qx}{(d_0 - d)g} \tag{8b}$$

where y is the upward or downward deformation of the neutral axis of the equivalent beam and a, b, and q are as defined by equations 4, 5, and 6. Practically, this is the same as the uplift or depression of the surface relative to the original level of the continental surface or the sea bottom. This equation adequately describes the figure of the overriding or continental sector if in the expressions for q we adopt $d=0$ because, at first, we neglect the unloading of the raised fault scarp due to erosion. On the underriding or seaward sector, one adopts for d the density of sea water because, in general, the depressed section is flooded with sea water as soon as it is depressed. Except for this slight difference, the continental and seaward deformations are inverted but similar to each other. The reader may verify that Eq. (8b) above is equivalent to Eq. (19) of reference 3a.

It is important next to discuss the fibre stresses in the lithosphere induced by the shear failure and overriding of the lithosphere. The fibre stress S_f may be calculated from Eq. (8a) by employing the well known relation[3c]

$$S_f = \frac{ET}{2} \frac{d^2y}{dx^2} \tag{9}$$

whence formulating Eq. (9) using Eq. (8) it is found that

$$\frac{S_f}{S} = \frac{6 \cos \phi \sin \phi}{Tb} \epsilon^{-ax} \sin bx \tag{10}$$

and this has a maximum fibre stress at the value of x defined by

$$\tan bx = \frac{b}{a} \cdot \tag{11}$$

One is now in a position to draw to scale the expected figures and deformations of the lithosphere and predict with some certainty where secondary failure may be expected as the lithosphere is bent more and more by the applied horizontal compressive forces.

The diagram of Fig. 1 shows the expected configuration of a section of the lithosphere after shear failure has occurred and sufficient subsequent compression has caused enough overriding to produce equilibrium. Because of the steepness of the surface slopes adjacent to the fault, rapid erosion of the upraised section will transport sediments to the shoreward edge of the adjacent deep and the initial sharp surface discontinuities will be largely erased. Except for this transfer of sediments, the actual deformation is identical with that given by Eq. (8b) and plotted in Fig. 1. The vertical force $ST \cos \phi \sin \phi$ may be considered as being applied at the center of the shear plane or at $x = T \cot \phi/2$ if the origin is chosen near the continental boundary to coincide with the intersection of the fault plane with the surface. Having in mind the fact that sediments from the upraised fault will be deposited in the adjacent oceanic sector and that the figures of the overrunning and underrunning segments are essentially the same, it is geometrically legitimate to assume that the origin will lie approximately halfway between the top of the mountain ridge and the bottom of the deep. Now, noting from Eq. (11) that the maximum fibre stress due to the overriding lithosphere occurs at a distance

$$x = \frac{1}{b} \tan^{-1} \frac{b}{a} \tag{12}$$

from the effective point of application of the principal deforming force $ST \cos \phi \sin \phi$, one may write that

$$x_0 = \frac{T}{2} \cot \phi + \frac{1}{b} \tan^{-1} \frac{b}{a} \tag{13}$$

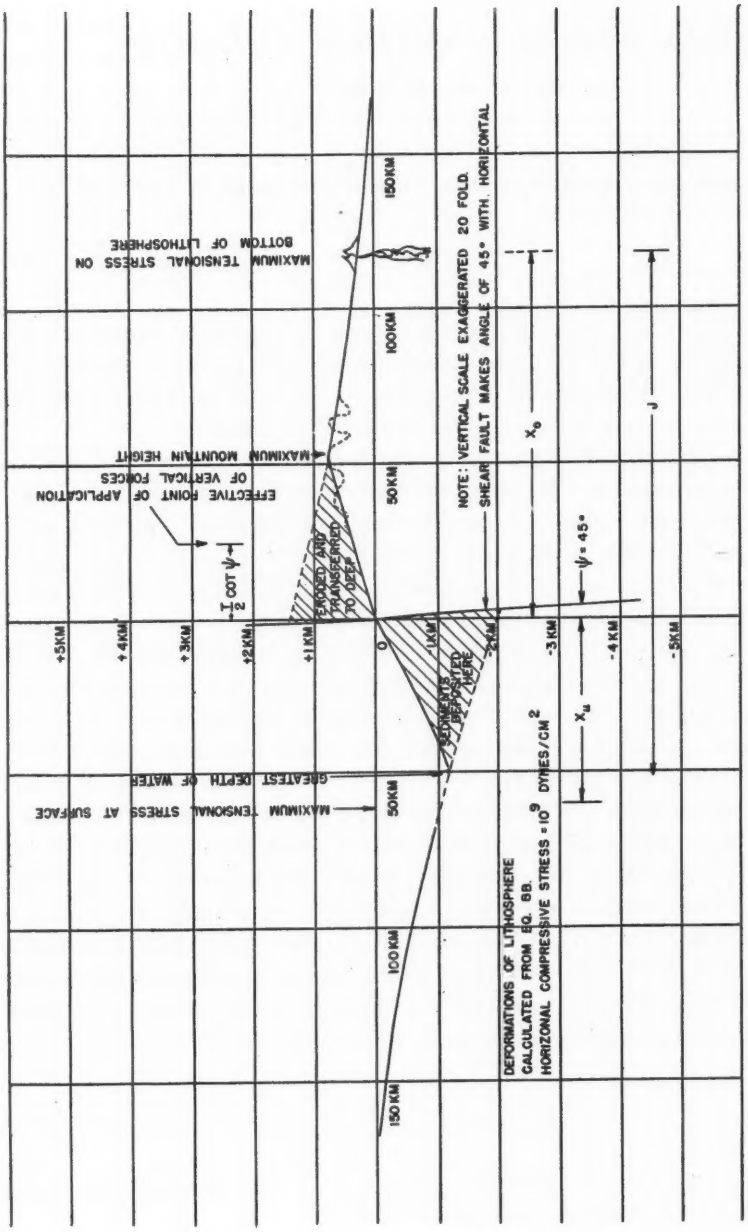


FIG. 1. Calculated deformation of a shear fractured lithosphere subject to a horizontal compressive stress of 10^9 dynes/cm^2.

where x_0 is the distance from the origin to the point on the overthrusting sector where maximum fibre stress is produced and where a secondary mechanical failure is most likely to take place. Because of the difficulty of precisely locating the position of the thrust fault at the surface, it is sometimes more convenient to employ

$$J = \frac{A}{2} + \frac{T}{2}\cot\phi + \frac{1}{b}\tan^{-1}\frac{b}{a} \tag{14}$$

where J is the horizontal distance from the bottom of the deep to the zone of maximum fibre stress and A is the horizontal distance from the bottom of the deep to the top of the adjacent mountain range. In a similar manner

$$x_u = \frac{1}{b}\tan^{-1}\frac{b}{a} - \frac{T}{2}\cot\phi \tag{15}$$

where x_u is the distance from the origin to the zone of maximum fibre stress on the underthrusting sector.

COMPARISON OF DEDUCED QUANTITATIVE ESTIMATES WITH AN ACTUAL GEOLOGICAL STRUCTURE

Prediction is the legitimate child of forward-looking quantitative investigation. It is of interest, therefore, to employ the above quantitative estimates derived only from well established mechanical principles and see how these estimates agree with actual geological structures. Adopting the Mexican coastal area discussed by Hobbs[2] as a suitable one for test, one compares estimates and observation in relation to (a) depth of the deep, (b) the shape and width of the deep, (c) the height of the mountain range, (d) the shape and width of the mountain range, (e) the location of areas of maximum stress which we will show defines also the position of parallel rows of volcanoes, and (f) gravity anomalies.

Because of the extent of most continental coastlines and because the horizontal compressive stresses are applied over great areas, it should be clear that the deformed figure of the lithosphere defined by Eq. (8) is typical of every unit segment throughout the investigated area. This means, therefore, that each of the juxtaposed earth features forms a row parallel to the others and the deep, the mountain range and volcanic area may be thought of as forming a single geo-

logical unit of great length and total width defined by Eq. (8b) or π/q. The principal condition necessary for such a juxtaposed geological unit is a widespread compressional stress of sufficient magnitude to induce a shear fault at a previously stressed line of incipient weakness. There is no known way of directly measuring the magnitude of this horizontal stress acting on the lithosphere but the fact that it exists and is large can hardly be doubted. No great error will result if S is taken as some small number times 10^9 dynes/cm^2 because such stresses will appreciably deform ordinary rocks and such stresses are frequently observed at the earth's surface. Another important quantity is the lithospheric constant q defined by Eq. (6) that measures the ease of deformation of the lithosphere. One adopts from earlier studies of *observational data*[3b] $q=8.4\times10^{-8}$ cm^{-1} and by numerical substitution determines that a and b in Eqs. (4) and (5) are nearly equal and approximate the value of q. This adopted value of q by Eq. (6) may imply that E approximates 1.1×10^{12} dynes/cm^2 and $T=50\times10^5$ cm, but other combinations are possible. It is also necessary to know ϕ so it is taken as $\pi/4$ or 45°, which corresponds to the plane of maximum shear stress. No great error will result if the density of the underlying magma is taken as 3.1 gm/cm^3 and it is assumed to have no strength in shear.

With the foregoing data in mind, one proceeds to evaluate the numerical magnitudes of the various quantities associated with the various earth features and compare them with the observed magnitudes.

(a) *The Deep*

It may be noted from Eq. (8b) that the maximum deformation of the lithospheric thrust fault is directly proportional to the applied horizontal stress and it is this stress that produces and maintains the over- and underthrusting. This implies, that if the horizontal stress were suddenly released, the deep and the adjacent mountain range would relax and largely disappear in some 25,000 years.[3a] Substitution of the adopted quantities in Eq. (8b) and noting that the oceanic down-warp is submerged in sea water so that $d_0-d=2.1$ gms/cm^3, one finds that the maximum downward deformation of the lithosphere below its original position of equilibrium is 2.0 km if $S=10^9$ dynes/cm^2 or 4.0 km if S is taken as 2×10^9 dynes/cm^2. This maximum depth of deformation would at first exist close to the fault

scarp but due to the large slopes of the adjacent highlands, sediments will rapidly wash in and build outward from the coast, forming steep slopes on the landward side of the deep and gradually moving the zone of deepest water seaward. On the seaward side the depth and slopes will become progressively less in accordance with Eq. (8b). Evidently, too, the full width of the deep from the fault to the point of no deformation will, by Eq. (8b), be $x=\pi/2q$ or 190 km. However, sediments deposited near the steeper slopes and the considerable extent of rather small deformation may be expected to reduce the usually deep regions to about one-half the full width. Reference to available maps shows that the average depth of the Mexican deep is some 700 fathoms or 1.3 km deeper than the neighboring sea bottom. Because sediments have already been deposited in the deepest portion of the thrust fault, it is probably reasonable to suppose that the maximum downward deformation was about 2.0 km and thus is consistent with the above estimate. Attention is drawn to the fact that this deep is a geosyncline in the process of formation[3a] and that, if and when it is filled and the horizontal compression is released, the syncline will rise in accordance with the principles of isobaric equilibrium producing a great mountain chain. It seems physically possible that Lower California is such a risen geosyncline that has already reached maturity.

(b) *The Coastal Mountain Chain*

The overthrusting fault responsible for the rising coastal range also has its figure described by Eq. (8b) except that now d_0-d is obviously near 3.1 gms/cm^3, or the density of the underlying magma. The uneroded scarp is found to have a maximum elevation above the original continental level of 1.4 km if $S=10^9$ or 2.8 km if $S=2\times10^9$ dynes/cm^2. Erosion will reduce these values, particularly near the coast where the seaward slopes will necessarily be large. As the erosion proceeds, the position of the highest peaks will slowly migrate inland. Behind the main ridge of the coastal range, according to Eq. (8), the slopes will be more gentle and the heights of the secondary ridges will grow progressively less, approaching zero at $x=\pi/2q$ or 190 km. Upon comparison of these estimates with the Sierra Madre del Sur one is struck with the profound modifications that erosion can produce. About all one can say is that the present average height of the mountain range is about 1.3 km above the mean height of the North American continent (0.7 km) and therefore the

above calculation is at least not in disagreement with the observed structure.

(c) *The Zone of Maximum Fibre Stress Coincident with the Location of Volcanic Activity*

We now examine the regions outside the shear fault zone to see if the severe deformation of the lithosphere causes mechanical failure at any other place and produces important secondary phenomena. The distance of the zone of maximum fibre stress from the surface intersection of the shear plane (adopted as the origin) is, by Eq. (13), $x_0 = 25$ km$+93$ km or 118 km. Now if the origin lies nearly halfway between the bottom of the deep and the top of the mountain range and this total distance according to Hobbs' map is 120 km, it follows that J, the horizontal distance from the bottom of the deep to the point on the overthrusting sector where the fibre stress is a maximum and where a secondary mechanical failure may first be expected, approximates 178 km. Upon comparing this calculated distance with Hobbs' map, it is found that it closely approximates the distance (175 km) from the bottom of the deep to the row of new volcanoes that lies immediately behind the coastal mountain range. The approximate agreement between the calculated position of maximum stress and the observed position of the volcanic chain both for this area and also for the Javanese area[1] is considered to be important in providing a valuable clue as to the fundamental mechanism responsible for volcanoes. The distance from the deep to the stress zone on the underrunning or seaward side evidently by Eq. (15) is only 8 km and coincides more or less with the deep itself.

Now by Eq. (8) the deformation of the underthrusting sector is greater and the fibre stresses are systematically larger than in the overthrusting sector, but in spite of these higher stresses, nothing especially remarkable except an occasional seaquake appears in this area. In view of this circumstance, one is led to examine the differences produced in the two apparently similar cases to see if a clue cannot be found as to the causes and mechanisms responsible for the occurrence of volcanoes only on the landward or overrunning section of the lithosphere. An examination of the induced deformations of the continental and oceanic sectors shows that while the magnitude of the stresses in the oceanic sector is greater by 35%, the signs are oppositely distributed in the two regions. For example, on the continental sector the uppermost layers are in compression due both to the de-

formation and to the superposed horizontal compressive stress, while at the bottom of the lithosphere the deformational and superposed horizontal stresses are in a direction to neutralize each other. On the other hand, the stress pattern in the oceanic sector is reversed so that the compressional stresses are additive on the bottom of the crust and tend toward neutralization at the surface. Superposed on the above fibre stress system is the hydrostatic compression of the weak supporting magma which approximates 1.5×10^{10} dynes/cm^2 at the bottom of the lithosphere and approaches zero at the surface. It is easy to calculate from Eq. (10) that the maximum fibre stress due to deformation accompanying a typical mountain and adjacent deep is but slightly greater than the horizontal compressional stress, so that at the bottom of the section on the landward side, the stress in the x direction would approximate 10^9 dynes/cm^2 and actually be in tension were it not for the existence of the tremendous hydrostatic compressional stress in the adjacent magma. Because the lower boundary of the lithosphere marks the termination of rocks having appreciable strength, a tensional stress of 10^8 dynes/cm^2 may be expected to cause failure and fracture there. The resulting unsymmetrical stress distribution and particularly the existence of failure by tensional stress invite injection of the highly compressed fluid magma into the fractured regions in order to establish equilibrium. Further, because the injected magma has no appreciable strength, a slight failure of the crust near the bottom will be propagated upward through the lithosphere, producing earthquakes and a zone of weakness through which vertical channels may be cut by injection. This is thought to be the fundamental process that make possible the occurrence of volcanoes because it is easy to show, making reasonable assumptions as to the vertical distribution of densities, that the injection pressures are adequate actually to split the upper portions of the lithosphere.

On the seaward side of the fault, all deformations on the bottom of the crust are such as to produce compressive stress. This stress pattern superposed upon the hydrostatic stress of the magma will obviously not promote injection. Finally one should observe that the tensional stresses on the surface of the oceanic sector are approximately neutralized by the primary horizontal compression of the equivalent beam and because no large hydrostatic stress is present there, one would not expect a mechanical failure. The analysis therefore leads to the conclusion that on the overthrusting side of a shear fault and removed from its surface trace by about

118 km, a zone of tensional stress should be found on the bottom of the lithosphere that has such properties as to encourage the injection of the underlying magma. One may conclude, therefore, that the distribution of stress and the expected mode of failure of the highly deformed lithosphere under horizontal compression are such as to produce a marked asymmetry and that the occurrence of volcanic ranges only on the overriding sector is just what one would predict from the stress pattern.

(d) *Gravity Anomalies*

The relation of the systematic deformations of the lithosphere to the occurrence of gravity anomalies and to the principle of isobaric equilibrium has been considered at length by the author in a series of quantitative papers.[3b,c,d,e] Their review here seems impractical and one need only note that large negative gravity anomalies may be expected on the landward side and edge of the deep but decreasing toward the sea much like the downward deformation decreases. Calculating from Eq. (29) of reference 3b, using $b=q=8.4\times10^{-8}$ cm^{-1} and $S=10^9$ dynes/cm^2, it is found that the maximum negative gravity anomaly will approximate 150 milligals near the origin and decrease toward the sea in accordance with Eq. (29). The principal term of the anomaly near the deepest water is estimated to approximate 85 milligals. If $S=2\times10^9$ dynes/ cm^2, then the anomalies are everywhere doubled.

In the absence of erosion, positive anomalies having the same distribution landward will be produced, but it must be noticed that the transfer of sediments from the overriding fault scarp to the adjacent edge of the deep removes loading from the overriding segment and adds it to the underthrusting segment. It is estimated that maximum positive values of 100 milligals may be encountered in the mountainous areas well back from the coast, decreasing inland more or less in accordance with Eq. (29) of reference 3b.

As far as the author is aware, there are no coherent data for the gravity anomalies across the Mexican zone studied above, but such estimates have also been made for the deep located south of Java. There, the calculated and observed values agree to the accuracy that the values of the horizontal compressive stress are known so that the Mexican predictions are probably justified.

CONCLUSION

It should be apparent from the above calculated properties of the

deep, mountain and volcano chain, that the mechanical characteristics of a highly compressed shear fault lead to parallel structures that possess a definite geometry and look remarkably like actual geological structures not only in the Mexican area but also the Javanese zone. Moreover, because the deformations increase regularly with the applied horizontal stress it may well be that Hobbs[2] comments on the "coastal staircase" are quite significant. It is quite evident that the calculated effects and those actually observed cannot be identical because the detailed effects of sedimentary transfer can not be quantitively stated. But reasonable assumptions in regard to the magnitude and the distances that material is transferred make the estimated and actual pictures more nearly the same. The writer thinks that the agreements as exhibited by Fig. 1 are quite satisfying in view of the wide range of geological phenomena that is described and the fact that the horizontal compressive stress, taken as $S = 10^9$ dynes/cm^2, is imperfectly known.

If the above analysis is substantially correct, it follows that long linear shear faults near a continental boundary induced by a continuing horizontal compression will *simultaneously* produce juxtaposed deeps, mountain chains and rows of volcanoes, each earth feature bearing a definite mechanical and geometrical relation to the others. The spacing and relative positions can be specified from purely mechanical considerations, provided only that the elastic properties of the lithosphere are given and that it is supported on a weak underlying magma. The investigation has ignored a number of details that may somewhat modify the numerical agreements but no reasonable change in constants or assumptions would destroy the general similarity of the calculated and observed structures.

PATENTS*

Starting with this issue the patent abstracts in GEOPHYSICS will be classified into a group of subject headings each carrying an identifying number. The classification system is presented in detail at this time. It is also to be used in the subject classification portion of the patent index section of the Cumulative Index of GEOPHYSICS, to be published this year.

The complete list of classifications is given here for reference (but will not be reprinted in following issues). The numbers preceding each classification are those used for reference in the Cumulative Index. These numbers are not consecutive, but at intervals of four, to permit introducing new classifications later without disturbing the present system.

Ref. No.

4 ACCELEROMETER
see also TRANSDUCER and specific subjects listed thereunder

8 ACOUSTIC LOGGING
see also ACOUSTIC MEASUREMENTS, CONTINUOUS WAVE SEISMIC TESTING, and specific subjects listed under SEISMOGRAPH PROSPECTING

12 ACOUSTIC MEASUREMENTS
see also ACOUSTIC LOGGING, SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

16 AIRPLANE FLIGHT INSTRUMENTS
see also BAROMETER, MAGNETIC COMPASS, RADIO NAVIGATION, RADIO RANGING

ALTIMETER
see AIRPLANE FLIGHT INSTRUMENTS, BAROMETER

20 BARGE

24 BAROMETER
see also AIRPLANE FLIGHT INSTRUMENTS, PRESSURE GAUGE

BIOLOGICAL PROSPECTING
see BIOLOGICAL SOIL ANALYSIS

28 BIOLOGICAL SOIL ANALYSIS
see also specific subjects listed under GEOCHEMICAL PROSPECTING

32 BLASTING MACHINE
see also EXPLOSIVE

36 BOTTOM HOLE SAMPLER
see also CASING PERFORATOR, CORE BARREL, SIDE WALL SAMPLER

40 CABLE

44 CALIPER LOGGING
see also MECHANICAL LOGGING

48 CASING PERFORATOR
see also BOTTOM HOLE SAMPLER, CORE BARREL, SIDE WALL SAMPLER

* Abstracts and classification by O. F. Ritzmann, Gulf Oil Corporation.

52 CASING TESTING

56 CATHODIC PROTECTION

60 CEMENT LOCATING
see also GAMMA RAY LOGGING, NEUTRON LOGGING, RADIOACTIVITY LOGGING

64 COMMUNICATION DEVICE
see also WELL SIGNALING

68 COMPUTING DEVICES

72 CONNATE WATER TESTING
see also CORE TESTING, WATER LOCATING

76 CONTINUOUS WAVE SEISMIC TESTING
see also ACOUSTIC LOGGING, SEISMOGRAPH PROSPECTING

80 CORE BARREL
see also BOTTOM HOLE SAMPLER, CASING PERFORATOR, SIDE WALL SAMPLER

84 CORE ORIENTATION
see also CORE TESTING, MAGNETIC LOGGING

88 CORE TESTING
see also CONNATE WATER TESTING, CORE ORIENTATION, MAGNETIC LOGGING, MAGNETIC TESTING, PERMEABILITY TESTING, POROSITY TESTING, WATER LOCATING

DEPTH MEASUREMENTS (in wells)
see WELL SURVEYING

92 DRILL
see also EARTH AUGER

DRILL CUTTING SAMPLER
see MUD SAMPLER

96 DRILLING MUD

100 DRILLING RATE RECORDER
see also RECORDER and subjects listed thereunder

104 EARTH AUGER
see also DRILL

108 ECHO SOUNDING
see also RADIO NAVIGATION, RADIO RANGING, SEISMOGRAPH PROSPECTING, SONIC FLUID LEVEL MEASUREMENT. SUBMARINE SIGNALING, TIME INTERVAL METER

112 ELECTRIC CONNECTOR

116 ELECTRIC LOGGING
see also ELECTROMAGNETIC LOGGING

120 ELECTRIC TRANSIENT PROSPECTING

124 ELECTRICAL PROSPECTING
see also ELECTRIC LOGGING, ELECTRIC TRANSIENT PROSPECTING, ELECTROMAGNETIC LOGGING, ELECTROMAGNETIC PROSPECTING, RADIO WAVE PROSPECTING

128 ELECTROMAGNETIC LOGGING
see also ELECTRIC LOGGING

132 ELECTROMAGNETIC PROSPECTING
see also ELECTROMAGNETIC LOGGING, ELECTRICAL PROSPECTING and specific subjects listed thereunder

136 EXPLOSIVE
see also BLASTING MACHINE, SEISMOGRAPH PROSPECTING, SHOT MOMENT RECORDING, UP-HOLE IMPULSE RECORDING, WELL SHOOTING

140 FLAW DETECTOR

144 FLOW LOGGING
see also FLOW METER

148 FLOW METER
see also FLOW LOGGING

FLUID LOGGING
see FLOW LOGGING, MUD LOGGING, WATER LOCATING

152 FLUORESCENCE LOGGING
see also LOGGING WHILE DRILLING, MUD LOGGING

156 FOLLOW-UP DEVICES
see also MOTION TESTING

FORMATION TESTER
see FLOW LOGGING, WELL TESTER

160 GALVANOMETER
see also RECORDER and subjects listed thereunder

164 GAMMA RAY LOGGING
see also CEMENT LOCATING, NEUTRON LOGGING, RADIOACTIVITY LOGGING, RADIOACTIVITY MEASUREMENTS

168 GAS ANALYSIS
see also MASS SPECTROMETRY and specific subjects listed under GEOCHEMICAL PROSPECTING

172 GEOCHEMICAL PROSPECTING
see also BIOLOGICAL SOIL ANALYSIS, GAS ANALYSIS, MASS SPECTROMETRY, MUD LOGGING, MUD REMOVAL, MUD SAMPLER, SOIL ANALYSIS, SOIL GAS SAMPLING, SOIL SAMPLING, WATER ANALYSIS

GEOCHEMICAL WELL LOGGING
see MUD LOGGING, also specific subjects listed under GEOCHEMICAL PROSPECTING

GEOPHONE
see specific subjects listed under TRANSDUCER

176 GRAVEL PACKING

180 GRAVIMETER
see also TORSION BALANCE

GRAVIMETRIC PROSPECTING
see GRAVIMETER, SPECIFIC GRAVITY MEASUREMENT, TORSION BALANCE

GUN PERFORATOR
see CASING PERFORATOR
HYDROPHONE
see ECHO SOUNDING, SUBMARINE SIGNALING, also specific subjects listed under TRANSDUCER
188 HYGROMETER
192 INCLINOMETER
see also ORIENTING DRILLING TOOLS, WELL SURVEYING
196 INFRARED MEASUREMENTS
see also SPECTROGRAPH, SPECTROPHOTOMETER
LEVEL
see GRAVIMETER
200 LEVEL INDICATORS (for containers, tanks)
see also RADIOACTIVITY MEASUREMENTS
204 LOGGING RECORDER
see also RECORDER and specific subjects listed thereunder
208 LOGGING WHILE DRILLING
see also MUD LOGGING
212 MAGNETIC SYSTEM
216 MAGNETIC COMPASS
see also AIRPLANE FLIGHT INSTRUMENTS
220 MAGNETIC LOGGING
see also CORE ORIENTATION
MAGNETIC PROSPECTING
see CORE ORIENTATION, MAGNETIC COMPASS, MAGNETIC LOGGING, MAGNETIC TESTING, MAGNETOMETER
224 MAGNETIC RECORDER
see also RECORDER and subjects listed thereunder
228 MAGNETIC TESTING
see also CORE TESTING, FLAW DETECTOR, and specific subjects listed under MAGNETIC PROSPECTING
232 MAGNETOMETER
236 MASS SPECTROMETRY
240 MECHANICAL LOGGING
see also CALIPER LOGGING
244 MICROPHONE
see also TRANSDUCER and subjects listed thereunder
MODULATED CARRIER RECORDING
see STRAIN GAUGE
248 MOTION TESTING
see also FOLLOW-UP DEVICES
252 MUD LOGGING
see also FLUORESCENCE LOGGING and specific subjects listed under GEOCHEMICAL PROSPECTING

256 MUD REMOVAL
see also MUD LOGGING and specific subjects listed under GEOCHEMICAL PROSPECTING

260 MUD SAMPLER
see also specific subjects tested under GEOCHEMICAL PROSPECTING, MUD LOGGING, MUD REMOVAL

264 NEUTRON LOGGING
see also CEMENT LOCATING, GAMMA RAY LOGGING, RADIOACTIVITY LOGGING, RADIOACTIVITY MEASUREMENTS

OIL LOCATING (in wells)
see CORE TESTING, WATER LOCATING, also various types of logging, sampler, etc.

268 OIL TESTING

272 ORIENTATING DRILLING TOOLS
see also INCLINOMETER, WELL SURVEYING

OSCILLOGRAPH
see GALVANOMETER

276 PERMEABILITY TESTING
see also CORE TESTING, POROSITY TESTING

280 PHOTOGRAPHIC LOGGING

284 POROSITY TESTING
see also CORE TESTING, PERMEABILITY TESTING

288 PRESSURE GAUGE
see also BAROMETER

292 PRODUCTIVITY TESTING

296 PUMPING APPARATUS

300 RADIATOR GUARD

304 RADIOACTIVITY LOGGING
see also CEMENT LOCATING, GAMMA RAY LOGGING, NEUTRON LOGGING, RADIOACTIVITY MEASUREMENTS

308 RADIOACTIVITY MEASUREMENTS
see also CEMENT LOCATING, GAMMA RAY LOGGING, LEVEL INDICATORS, NEUTRON LOGGING, RADIOACTIVITY LOGGING

RADIOACTIVITY PROSPECTING
see RADIOACTIVITY MEASUREMENTS, RADIOACTIVITY LOGGING

312 RADIO NAVIGATION
see also AIRPLANE FLIGHT INSTRUMENTS, ECHO SOUNDING, RADIO RANGING, SUBMARINE SIGNALING, TIME INTERVAL METER

316 RADIO RANGING
see also AIRPLANE FLIGHT INSTRUMENTS, ECHO SOUNDING, RADIO NAVIGATION, SUBMARINE SIGNALING, TIME INTERVAL METER

320 RADIO WAVE PROSPECTING
see also ELECTROMAGNETIC PROSPECTING, ELECTROMAGNETIC LOGGING

324 RECORDER
see also DRILLING RATE RECORDER, GALVANOMETER, LOGGING RECORDER, MAGNETIC RECORDER, SEISMOGRAPH RECORDER, SEISMOGRAPH TIMING, TIMEPIECE TESTING

328 RELAY

RESISTIVITY MEASUREMENTS
see ELECTRICAL PROSPECTING, ELECTRIC LOGGING

ROUGHNESS LOGGING
see MECHANICAL LOGGING

332 SEA SAMPLER

336 SECONDARY RECOVERY

340 SEISMIC-ELECTRIC EFFECT
see also SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

SEISMIC LOGGING
see ACOUSTIC LOGGING

344 SEISMOGRAPH AMPLIFIER
see also SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

348 SEISMOGRAPH FILTER
see also SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

352 SEISMOGRAPH INTERPRETATION
see also SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

356 SEISMOGRAPH MIXING
see also SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

360 SEISMOGRAPH PROSPECTING
see also other subjects beginning SEISMOGRAPH—also ACOUSTIC LOGGING, ACOUSTIC MEASUREMENTS, CONTINUOUS WAVE SEISMIC TESTING, ECHO SOUNDING, EXPLOSIVE, RECORDER, SEISMIC-ELECTRIC EFFECT, SHOT MOMENT RECORDING, SUBMARINE SIGNALING, TRANSDUCER, UP-HOLE IMPULSE RECORDING, WELL SHOOTING

364 SEISMOGRAPH RECORDER
see also RECORDER and SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

368 SEISMOGRAPH TIMING
see also TIMEPIECE TESTING and SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

372 SEISMOGRAPH VOLUME CONTROL
see also SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

376 SEISMOMETER
see also TRANSDUCER and SEISMOGRAPH PROSPECTING and subjects listed thereunder

380 SEISMOMETER TESTING
see also CONTINUOUS WAVE SEISMIC TESTING

SHOOTING TECHNIQUE
see EXPLOSIVE, SEISMOGRAPH PROSPECTING, SHOT HOLE CASING, SHOT MOMENT RECORDING, UP-HOLE IMPULSE RECORDING

384 SHOT HOLE CASING

388 SHOT MOMENT RECORDING
see also EXPLOSIVE, SEISMOGRAPH PROSPECTING, UP-HOLE IMPULSE RECORDING

SHOT POINT
see EXPLOSIVE, SEISMOGRAPH PROSPECTING, SHOT HOLE CASING, SHOT MOMENT RECORDING, UP-HOLE IMPULSE RECORDING

392 SIDE WALL SAMPLER
see also BOTTOM HOLE SAMPLER, CASING PERFORATOR, CORE BARREL

396 SOIL ANALYSIS
see also specific subjects listed under GEOCHEMICAL PROSPECTING

SOIL GAS ANALYSIS
see GAS ANALYSIS

400 SOIL GAS SAMPLING
see also specific subjects listed under GEOCHEMICAL PROSPECTING

404 SOIL SAMPLING
see also specific subjects listed under GEOCHEMICAL PROSPECTING

408 SONIC FLUID LEVEL MEASUREMENT
see also ECHO SOUNDING, MICROPHONE, PRODUCTIVITY TESTING, WELL SURVEYING

412 SPECIFIC GRAVITY MEASUREMENTS

416 SPECTROGRAPH
see also INFRARED MEASUREMENT, MASS SPECTROMETRY, SPECTROPHOTOMETER

420 SPECTROPHOTOMETER
see also INFRARED MEASUREMENTS, SPECTROGRAPH

424 SPEED CONTROL

428 STRAIN GAUGE
see also PRESSURE GAUGE, TRANSDUCER

SUBMARINE GEOPHYSICAL PROSPECTING
see under specific method or apparatus used, e.g. ECHO SOUNDING,

GRAVIMETER, SEISMOGRAPH PROSPECTING, SUBMARINE SIGNALING, TRANSDUCER.

432 SUBMARINE LOCATOR

436 SUBMARINE SIGNALING
see also ECHO SOUNDING, SEISMOGRAPH PROSPECTING, TRANSDUCER

SUPERSONIC SIGNALING
see ECHO SOUNDING, SUBMARINE SIGNALING, TRANSDUCER

440 SURFACE TESTING
see also TRANSDUCER and subjects listed thereunder

444 SURVEYING APPARATUS
see also AIRPLANE FLIGHT INSTRUMENTS, BAROMETER, WELL SURVEYING

448 TENSION INDICATOR

452 THERMAL LOGGING
see also THERMAL PROSPECTING, THERMOMETER

456 THERMAL PROSPECTING
see also THERMAL LOGGING, THERMOMETER

460 THERMOMETER
see also THERMAL LOGGING, THERMAL PROSPECTING

464 THERMOSTAT CONTROL

468 TIME INTERVAL METER
see also ECHO SOUNDING, RADIO RANGING

472 TIMEPIECE TESTING

TORQUE MEASUREMENT
see STRAIN GAUGE

476 TORSION BALANCE
see also GRAVIMETER

480 TRACER
see also RADIOACTIVITY MEASUREMENTS and subjects listed thereunder

484 TRANSDUCER
see also ACCELEROMETER, FLAW DETECTOR, MICROPHONE, MOTION TESTING, SEISMOMETER, STRAIN GAUGE, SUBMARINE SIGNALING SURFACE TESTING, VIBROMETER

488 UP-HOLE IMPULSE RECORDING
see also EXPLOSIVE, SEISMOGRAPH PROSPECTING, SHOT MOMENT RECORDING

VELOCITY DETERMINATION
see ACOUSTIC LOGGING, SEISMOGRAPH PROSPECTING

492 VIBROMETER
see also TRANSDUCER and subjects listed thereunder

496 VISCOSIMETER

500 VOLTMETER

504 WATER ANALYSIS
see also specific subjects listed under GEOCHEMICAL PROSPECTING

508 WATER LOCATING (in wells)
see also CONNATE WATER TESTING, CORE TESTING, various types of logging, samplers, etc.

WEIGHT INDICATOR
see TENSION INDICATOR

WELL LOGGING
see under specific type of logging, samplers, etc., also CABLE, CEMENT LOCATING, DRILLING RATE RECORDER, LOGGING WHILE DRILLING, SONIC FLUID LEVEL MEASUREMENT, WATER LOCATING, WELL SURVEYING

512 WELL SHOOTING
see also EXPLOSIVE, SEISMOGRAPH PROSPECTING and specific subjects listed thereunder

516 WELL SIGNALING
see also WELL SURVEYING and subjects listed thereunder

520 WELL SURVEYING
see also INCLINOMETER, ORIENTING DRILLING TOOLS, SONIC FLUID LEVEL MEASUREMENT, WELL SIGNALING

524 WELL TESTER (for production)
for well logging and well surveying tools see under specific subject

528 WELL TOOL
for well logging and well surveying tools see under specific subject

532 WELL TREATING

4—ACCELEROMETER

U. S. No. 2,411,401. W. P. Welch. Iss. 11/19/46. App. 7/28/42. Assign. Westinghouse Electric Corp.

Accelerometer. A piezoelectric vibrometer in which a small mass is mounted on a pair of quartz pressure crystals and the charge generated on vibration is measured on a c-r tube.

8—ACOUSTIC LOGGING

See O. S. Petty, *Measuring Instrument;* Class 376.

12—ACOUSTIC MEASUREMENTS

U. S. No. 2,412,240. F. W. Williams and J. Clark. Iss. 12/10/46. App. 7/16/43.

Method and Means for Testing for Imperfections in Vibratable Objects. A method of detecting flaws by repeatedly striking the object with an electrically driven vibrating striker, picking up the vibrations and observing them with a c-r tube or a distortion meter.

16—AIRPLANE FLIGHT INSTRUMENTS

U. S. No. 2,410,006. D. Blitz. Iss. 10/29/46. App. 5/30/44. Assign. Radio Corp. of America.

Balanced Detector for Altimeters. A balanced detector for an F-M type of aircraft radio altimeter using coupled loops of transmission line.

U. S. No. 2,410,122. W. R. Mercer and B. R. Cole. Iss. 10/29/46. App. 6/9/44. Assign. Radio Corp. of America.

Balanced Detector for Altimeters. A balanced detector for an F-M type of aircraft altimeter using coupled diodes to detect the modulation.

U. S. No. 2,412,003. J. Neufeld. Iss. 12/3/46. App. 6/16/42.

Navigational Method and Apparatus. A radio terrain contour indicator in which a vertically directed radio altimeter signal is compared with a 60° forward directed radio altimeter signal and the ratio of the difference in altitudes to the vertical altitude indicated.

U. S. No. 2,412,111. W. S. Wilson. Iss. 12/3/46. App. 12/30/43. Assign. Radio Corp. of America.

Measurement of Time Between Pulses. A circuit for measuring the time interval between radio frequency pulses in which the pulses are applied to tubes to produce a square wave whose duration is proportional to the interval and is measured on a d-c meter.

U. S. No. 2,412,541. P. F. Shivers. Iss. 12/10/46. App. 11/20/42. Assign. Minneapolis-Honeywell Regulator Co.

Altimeter. An atmospheric pressure aneroid type of altimeter having manual compensation for ground air temperature and pressure and automatic compensation for air temperature at point of measurement.

U. S. No. 2,413,349. D. Hancock, Jr. and H. E. Meinema. Iss. 12/31/46. App. 4/17/44

Camera for Aerial Photography. A strip camera in which the frequency of an a-c generator on the film roller is compared with the signal from a photocell onto which the terrain image is projected through a grating and the film speed controlled so as to maintain proper frequency relationship.

See also R. T. Hurley, *Aircraft Control Apparatus;* Class 24.

J. D. Morgan and P. B. Levitt, *Rate of Rise-Dive Indicator;* Class 288.

24—BAROMETER

U. S. No. 2,410,502. R. T. Hurley. Iss. 11/5/46. App. 4/6/40. Assign. Bendix Aviation Corp.

Aircraft Control Apparatus. A barometric altitude controller in which the diaphragm deflection of an aneroid barometer is detected by a Pulfrich-Fizeau interferometer and the fringes allowed to fall on photocells operating the controls.

See also P. F. Shivers, *Altimeter;* Class 16.

28—BIOLOGICAL SOIL ANALYSIS

U. S. No. 2,413,278. C. E. Zobell. Iss. 12/24/46. App. 3/17/44. Assign. American Petroleum Institute.

Bacteriological Process for Treatment of Fluid-Bearing Earth Formations. A method of secondary recovery in which bacteria of the type desulfovibrio hydrocarbonoclasticus are introduced into the formation to increase porosity, depress surface tension and increase gas pressure.

64—COMMUNICATION DEVICE

U. S. No. 2,410,426. D. H. Chaney, U.S.A. Iss. 11/5/46. App. 5/3/45.

Control System for Remotely Positioned Radio Apparatus. A two wire remote control circuit for a radio transmitter and receiver with a switching relay arranged so that the circuit may be used either for microphone or head set.

U. S. No. 2,413,348. J. H. Hammond, Jr. Iss. 12/31/46. App. 2/10/40 and 11/12/42. Assign. Radio Corp. of America.

Signaling System. A phase modulated transmission system having the carrier wave displaced 90° and in which the receiver separately detects the upper and lower side bands displaced in phase by 180° and combines them in opposition to reproduce the original signal while cancelling interfering amplitude effects.

76—CONTINUOUS WAVE SEISMIC TESTING

U. S. No. 2,410,170. B. J. Lazan. Iss. 10/29/46. App. 11/18/43.

Oscillator. A motor driven mechanical oscillator having two sets of rotating eccentric weights on concentric shafts with an adjustable key in a spiral groove between them to adjust their relative eccentricity for changing their dynamic effect.

80—CORE BARREL

U. S. No. 2,412,915. B. W. Sewell. Iss. 12/17/46. App. 6/15/42. Assign. Standard Oil Development Co.

Pressure Core Barrel. A wire line operated pressure core barrel having on its lower end a ball valve which closes when the barrel is withdrawn and on its upper end a gasket seal held by tension on the withdrawing stem.

See also E. F. Aston, *Core Drill;* Class 92.

92—DRILL

U. S. No. 2,410,959. H. S. Brown. Iss. 11/12/46. App. 9/12/41 and 12/13/43.

Earth Drill. A truck mounted portable drilling rig which folds down over the truck cab in moving and which can drill holes at an angle to the vertical.

U. S. No. 2,412,939. E. F. Aston. Iss. 12/24/46. App. 6/25/45.

Core Drill. A core drill for obtaining a core from hardened steel armor plate having tungsten carbide bits with a small angle of negative axial rake and a small angle of negative radial rake.

104—EARTH AUGER

U. S. No. 2,411, 627. J. C. Jaques. Iss. 11/26/46. App. 3/21/46.

Earth Auger. An earth auger mounted on a tractor and driven by the tractor engine.

108—ECHO SOUNDING

U. S. No. 2,408,395. J. B. Hays, Jr. Iss. 10/1/46. App. 4/26/44. Assign. Western Electric Co., Inc.

Object Locating System. A submarine sound ranging system in which the signal from one hydrophone is delayed and compared in quadrature with the signal from the other

hydrophone, deviation from quadrature being detected by observing the difference between the sum and difference of the signals.

U. S. No. 2,408,458. E. E. Turner, Jr. Iss. 10/1/46. App. 1/5/40 and 7/25/41. Assign. Submarine Signal Co.

Apparatus for Echo Distance Measurement. A sensitivity control for an echo sounding apparatus using a voltage sensitive recording tape and in which the stylus runs on a metal track when off the tape and having a condenser which gradually charges up to put an aiding bias voltage on the stylus.

U. S. No. 2,410,065. B. M. Harrison. Iss. 10/29/46. App. 8/6/35. Assign. Submarine Signal Co.

Electrical Circuits. An echo sounding circuit using a single transducer for both sending and receiving and having the transducer in series with the driver output transformer secondary, a tuning condenser and a smaller auxiliary inductance across which the receiver amplifier is connected.

U. S. No. 2,410,805. R. Black, Jr. Iss. 11/12/46. App. 1/16/42. Assign. Bell Telephone Laboratories, Inc.

Vibration Detector. A hydrophone having an inertia type transducer embedded in a cylindrical body of soft rubber with cable attachments at each end.

U. S. No. 2,410,806. R. Black, Jr. and F. F. Romanow. Iss. 11/12/46. App. 1/9/42. Assign. Bell Telephone Laboratories, Inc.

Submarine Signal Detector. A hydrophone having a telephone receiver with an outward flaring frusto-conical opening which is closed on the outside by a relatively thick soft rubber diaphragm.

U. S. No. 2,411,071. E. J. Wade. Iss. 11/12/46. App. 7/13/43. Assign. General Electric Co.

Locating Equipment. An echo sounding amplifier having a remote cut-off input stage whose avc has a time constant intermediate the pulse width and pulse interval, and a sharp cut-off output stage whose avc has a time constant faster than the pulse width.

U. S. No. 2,411,146. I. C. Clement. Iss. 11/19/46. App. 6/14/33 and 9/29/36. Assign. Submarine Signal Co.

Sound Signaling Apparatus. A hydrophone in which regions of the diaphragm are connected by rods to the free corners of Rochelle-salt bending crystals.

U. S. No. 2,412,234. E. E. Turner, Jr. Iss. 12/10/46. App. 1/5/40 and 11/22/40. Assign. Submarine Signal Co.

Apparatus for Echo Distance Measurement. An echo sounding recorder on which the zero may be suppressed by advancing the cam which initiates the transmitted signal.

116—ELECTRIC LOGGING

U. S. No. 2,411,843. C. B. Aiken. Iss. 12/3/46. App. 9/24/42. Assign. Schlumberger Well Surveying Corp.

Compensating Means for Electrical Borehole Apparatus. A system in which a number of logging parameters are transmitted to the surface over a single cable by using different frequencies, one of the channels being used to transmit borehole temperature and for either manual or automatic correction of the readings of the other channels.

See also D. Silverman, *Well Logging;* Class 508.

136—EXPLOSIVE

U. S. No. 2,412,581. D. D. Huyett and F. S. Pollack. Iss. 12/17/46. App. 1/22/40. Assign. Atlas Powder Co.

Sheathing for Explosives. An explosive assembly in which the dynamite is inserted in a central hole in an annular cardboard cylinder whose annular space is filled with flame suppressing material.

See also M. M. Shapiro, *Piezoelectric Gauge and Method of Making the Same;* Class 244.

140—FLAW DETECTOR

U. S. No. 2,410,803. W. C. Barnes and H. W. Keevil. Iss. 11/12/46. App. 4/8/40.

Method and Apparatus for Detecting Flaws in Rails. A magnetic rail flaw detector unit which tests the under side of the rail head on the flange side and is automatically moved out of the way when obstructions are encountered.

See also H. C. Drake, *Rail Flaw Detector Mechanism;* Class 228.

H. C. Drake, *Flaw Detector for Tubing;* Class 228.

R. G. Rhodes, *Radiographic Inspection Method;* Class 304.

F. W. Williams and J. Clark, *Method and Means for Testing for Imperfections in Vibratable Objects;* Class 12.

148—FLOW METER

U. S. No. 2,409,430. C. V. Greenleaf. Iss. 10/15/46. App. 5/1/44.

Flow Indicator for Pipe Lines. A short transparent plastic section of pipe line with conducting rings in the flanges and longitudinal conducting bars between them so as to conduct static electricity, flow through the pipe being indicated by suspended arrow shaped vanes.

U. S. No. 2,411,613. F. LeG. Bryant. Iss. 11/26/46. App. 5/25/42. Assign. Jensen Machinery Co., Inc.

Metering Device. A rotating vane type fluid flow meter in which the moving vane interrupts a light beam to a photocell and impulses are counted.

U. S. No. 2,413,352. H. A. Hulsberg. Iss. 12/31/46. App. 3/30/44. Assign. Universal Oil Products Co.

Flowmeter. A flowmeter having a ball in a transparent tube bent into an arc with the fluid entering horizontally at the bottom and leaving vertically at the top, the ball being carried part way up by the flow and its position read on a scale.

160—GALVANOMETER

U. S. No. 2,410,379. C. M. Hathaway. Iss. 10/29/46. App. 9/25/44. Assign. Hathaway Instrument Co.

Galvanometer. A three phase watt galvanometer having three field coils on laminated core structures and a long galvanometer element carrying three coils with separate flexible leads but with a single short suspension and mirror.

168—GAS ANALYSIS

U. S. No. 2,412,359. E. E. Roper. Iss. 12/10/46. App. 12/1/43. Assign. Stanolind Oil and Gas Co.

Ionic Analysis. A method of gas analysis using a mass spectrometer in which the gas is diluted with a gas having a stable known ionic response so that standard conditions are maintained in the spectrometer.

164—GAMMA RAY LOGGING

See A. Frosch, *Well Logging;* Class 516.

192—INCLINOMETER

U. S. No. 2,412,976. W. H. Emerson and D. Hering. Iss. 12/24/46. App. 1/16/42. Assign. Sperry-Sun Well Surveying Co.

Well Surveying Instrument. A single shot pendulum inclinometer using electrolytic marking and having a centrifugal trip switch which opens the electric circuit by rotation of the drill stem to prevent further recording.

196—INFRARED MEASUREMENTS

U. S. No. 2,412,940. W. H. Avery. Iss. 12/24/46. App. 8/28/42.

Spectrometer Prism Mounting. A mounting for the prism of a spectrometer which will accommodate a number of prisms vertically above the other on a slide so that any one may be brought into use.

224—MAGNETIC RECORDER

U. S. No. 2,411,849. M. Camras. Iss. 12/3/46. App. 5/30/45. Assign. Armour Research Foundation.

Magnetic Recorder Head. A combined recording, reproducing and erasing head for a magnetic tape recorder with the recording-reproducing core of high permeability alloy and the erasing core of high saturation alloy and with the erasing coil also partially exciting the recording core.

U. S. No. 2,413,108. W. B. Latchford and L. C. Holmes. Iss. 12/24/46. App. 3/14/45. Assign. Stromberg-Carlson Co.

Recording and Reproducing Head for Magnetic Recording. A magnetic recorder head in which a small laminated core structure with coil is firmly clamped between surrounding bakelite end pieces so that small tape clearances may be used.

228—MAGNETIC TESTING

U. S. No. 2,409,553. H. C. Drake. Iss. 10/15/46. App. 4/13/43. Assign. Sperry Products, Inc.

Rail Flaw Detector Mechanism. Apparatus for disconnecting a rail flaw detector as it passes over joints, the untested space being adjustable by varying the angle of a rotating cam which actuates a disconnecting switch upon meeting a joint.

U. S. No. 2,409,554. H. C. Drake. Iss. 10/15/46. App. 6/16/44. Assign. Sperry Products, Inc.

Flaw Detector for Tubing. A magnetic pipe testing apparatus in which the end effect of successive tubes is reduced by putting them through in end to end contact and by automatically turning off the indicator as the joint is crossed.

U. S. No. 2,412,742. G. Muffly. Iss. 12/17/46. App. 11/13/44. Assign. Gulf Research & Development Co.

Disturbing Influence Detecting Element. A detecting circuit for a magnetic mine which trips on the approach of a disturbance and trips again when the disturbance begins to recede so as to fire close to the maximum of the disturbance.

232—MAGNETOMETER

U. S. No. 2,410,039. L. F. Beach. Iss. 10/29/46. App. 7/31/41. Assign. The Purves Corp.

Magnetic Field Responsive Device. A flux valve in which the primary exciting source is arranged to separately supply second hormonic and in which the indication is produced by the phase difference between the second harmonic induced in the secondary coil and that supplied by the source.

U. S. No. 2,412,046. S. C. Hoare. Iss. 12/3/46. App. 9/8/43. Assign. General Electric Co.

Resonant Circuit Saturable Core Measurement Apparatus. A unidirectional flux or compass indicator in which the wound saturable core forms a variable inductance in a tuned circuit, the effect of the flux being to alter the inductance and change the indicated response of the circuit.

236—MASS SPECTROMETRY

U. S. No. 2,412,236. H. W. Washburn. Iss. 12/10/46. App. 12/9/43. Assign. Consolidated Engineering Corp.

Mass Spectrometry. A mass spectrometer in which linear superposition of ion intensities of components is obtained by having the gas in the sample chamber at a pressure so low that the mean free path of each component is greater than the dimensions of the flow tube leading into the ionization chamber.

U. S. No. 2,412,237. H. W. Washburn and D. D. Taylor. Iss. 12/10/46. App. 12/9/43. Assign. Consolidated Engineering Corp.

Mass Spectrometry. A Method of analyzing a gas sample with a mass spectrometer by transferring the sample at a low pressure so that each component flows independent of the others, separately obtaining the ion spectrum for each component, and determining the analysis of the sample from a comparison of the sample spectrum with those of the individual components.

U. S. No. 2,413,668. H. W. Washburn. Iss. 12/31/46. App. 11/21/44. Assign. Consolidated Engineering Corp.

Mass Spectrometry. An ionizing apparatus for a mass spectrometer in which the gas flows out of a conducting chamber with a constricted outlet into a transverse ionizing

electron stream and into a second conducting chamber containing ion beam focussing electrodes.

See also E. E. Roper, *Ionic Analysis;* Class 168.

244—MICROPHONE

U. S. No. 2,408,816. M. M. Shapiro. Iss. 10/8/46. App. 2/10/44.

Piezoelectric Gauge and Method of Making the Same. An underwater explosion pressure gauge using a single quartz crystal held in a sealed metal case with one insulated electrode connected to a coaxial cable, the return connection being through the cable sheath and case.

U. S. No. 2,411,311. A. Wolf and L. G. Cowles. Iss. 11/19/46. App. 8/22/44. Assign. The Texas Co.

Well Sounding Microphone. A microphone for echo sounding in wells and having a Bourdon tube which actuates the stylus of a phonograph pick-up.

U. S. No. 2,411,865. L. G. Bostwick and J. H. King. Iss. 12/3/46. App. 2/10/44. Assign. Bell Telephone Laboratories, Inc.

Submarine Signaling Device. A low frequency hydrophone in which static pressure equalization on the diaphragm is obtained by flowing air to or from an auxiliary tank through a solenoid valve which is controlled by a micro-switch connected to the diaphragm through a mechanical filter.

See also R. Black, Jr., *Vibration Detector;* Class 108.

R. Black, Jr., and F. F. Romanow, *Submarine Signal Detector;* Class 108.

252—MUD LOGGING

U. S. No. 2,408,964. W. E. Winn and P. F. Dougherty. Iss. 10/8/46. App. 8/22/41. Assign. Sun Oil Co.

Method of Logging Wells. A method of logging drilling mud for hydrocarbons in which a portion of the mud stream is treated to standard conditions, hydrocarbons removed in a gas separator using carbon dioxide and then detecting and recording hydrocarbons in the gas.

U. S. No. 2,408,965. W. E. Winn and P. F. Dougherty. Iss. 10/8/46. App. 8/22/41. Assign. Sun Oil Co.

Method of Logging Wells. A method of logging drill cuttings for hydrocarbons in which the cuttings are heated in a bomb under high pressure of carbon dioxide gas and the gas analysed for hydrocarbons.

276—PERMEABILITY TESTING

U. S. No. 2,409,674. J. W. Graybeal. Iss. 10/22/46. App. 3/22/45. Assign. Standard Oil Development Co.

Determining Permeability of Subsurface Formations. A method and apparatus for permeability logging by introducing a slug of identifiable liquid into the well, forcing it into formations and measuring the pressure and rate of fall of an interface of the liquid.

U. S. No. 2,413,435. L. A. Courter. Iss. 12/31/46. App. 5/8/44. Assign. The Dow Chemical Co.,

Method of Determining Permeability of Earth Formations Penetrated by Well Bores. A method of permeability logging by introducing a known fluid into the well and introducing a lighter fluid above it at a known rate and observing the rate of descent of the interface by means of an electrode on a cable.

288—PRESSURE GAUGE

U. S. No. 2,412,740. J. D. Morgan and P. B. Levitt. Iss. 12/17/46. App. 4/14/45. Assign. Cities Service Oil Co.

Rate of Rise-Dive Indicator. A rate of rise-dive indicator for a submarine in which the sea water acts through a bellows to force a constant viscosity fluid into or out of a sump through an orifice and with the flow pressure indicated by a Bourdon gauge.

See also M. M. Shapiro, *Piezoelectric Gauge and Method of Making the Same;* Class 244.

304—RADIOACTIVITY LOGGING

U. S. No. 2,409,436. S. Krasnow and L. F. Curtiss. Iss. 10/15/46. App. 12/10/41. Assign. Geophysical Development Corp.

Method and Apparatus for Direct Recording of Borehole Radioactivity. A method of radioactivity logging in which a long length of protected photographic film is lowered into the well or in which the film is slowly reeled past a thin window in a case in the well.

308—RADIOACTIVITY MEASUREMENTS

U. S. No. 2,409,498. A. S. Keston. Iss. 10/15/46. App 10/27/44.

Geiger-Muller Counter. A self-quenching ionizing radiation counter filled with an organo-metallic vapor such as tetramethyl lead.

U. S. No. 2,412,174. R. G. Rhoades. Iss. 12/3/46. App. 6/24/46. Assign. Bechtel Brothers McCone Co.

Radiographic Inspection Method. A radiographic method of inspecting circumferential welds in pipe lines by making a small hole in the pipe near the weld, inserting a radium capsule on an arm which holds it in the center of the pipe and exposing a photographic film wrapped around the weld.

312—RADIO NAVIGATION

U. S. No. 2,413,620. G. Guanella. Iss. 12/31/46. App. 10/16/39 and 6/19/40. Assign. Patents Research Corp.

Direction Finding System. A radio direction finding system in which a transmitter at a known location sends out a frequency varying with a known schedule and the receiver picks up both the direct wave and the wave reflected from the ground, the beat note being a measure of the angle between them.

316—RADIO RANGING

U. S. No. 2,410,666. G. W. Leck. Iss. 11/5/46. App. 6/14/41. Assign. Radio Corp. of America.

Orienting Mechanism for Pulse Echo Systems. A scanning device for a radar system in which a directive antenna is mechanically moved over a spiral scanning path and the mechanism also connected to potentiometers feeding the c-r tube deflecting plates so that the electron beam moves synchronously with the antenna beam.

U. S. No. 2,410,868. L. de Forest. Iss. 11/12/46. App. 8/23/41.

Means and Method for Altitude Determination. A radio pulse echo type airplane altimeter in which the travel time of the pulse is determined by initiating the charging of a condenser on transmission and stopping the charging on reception and measuring the accumulated charge.

U. S. No. 2,413,637. B. D. Loughlin. Iss. 12/31/46. App. 9/15/44. Assign. Hazeltine Research, Inc.

Direction Indicating Device. A pulse modulated radio direction finding system in which four antennas are used for either receiving or transmitting and the difference in pulse arrival times used to control the time duration of a pulse applied to quadrature plates of a c-r tube indicator.

See also W. S. Wilson, *Measurement of Time Between Pulses;* Class 16.
G. Guanella, *Direction Finding Sytsem;* Class 312.

336—SECONDARY RECOVERY

See C. E. Zobell, *Bacteriological Process for Treatment of Fluid-bearing Earth Formations;* Class 28.

344—SEISMOGRAPH AMPLIFIER

U. S. No. 2,410,982. W. R. Koch. Iss. 11/12/46. App. 10/6/42 and 9/16/43. Assign. Radio Corp. of America.

Record Reproducing Circuit. An F-M phonograph reproducing circuit using a capacity pick-up connected to an oscillator.

U. S. No. 2,411,008. C. M. Sinnett. Iss. 11/12/46. App. 11/28/44. Assign. Radio Corp. of America.

Transducer System. An angle modulated F-M phonograph reproducing circuit in which the pick-up is connected to a reactance tube which is coupled to the oscillator.

372—SEISMOGRAPH VOLUME CONTROL

U. S. No. 2,410,303. O. S. Petty. Iss. 10/29/46. App. 8/18/39 and 5/27/43.

Seismic Surveying. An avc circuit for seismograph amplifiers in which the gain control is more effective in reducing the amplitude when high frequency signals are received than when low frequency signals are received.

376—SEISMOMETER

U. S. No. 2,408,478. O. S. Petty. Iss. 10/1/46. App. 3/14/40.

Seismic Apparatus and Method. A condenser type geophone in which the steady mass has an electromagnet whose traction is opposed to the suspension spring so that plate spacing and frequency may be controlled.

U. S. No. 2,411,117. S. A. Scherbatskoy. Iss. 11/12/46. App. 6/10/43. Assign. Seismic Engineering Co.

Seismometer. A seismometer in which the relative motion is imparted to one of two electrodes immersed in an electrolyte and the variations in resistance indicated.

U. S. No. 2,413,651. O. S. Petty. Iss. 12/31/46. App. 8/29/44.

Measuring Instrument. A seismic detector for use in a well, the instrument being in a cylindrical case filled with oil and having at its lower end a solid piston which may slide to establish pressure equalization inside and outside the case.

388—SHOT MOMENT RECORDING

U. S. No. 2,413,116. E. M. Shook and R. W. Olson. Iss. 12/24/46. App. 2/14/44. Assign. Socony-Vacuum Oil Co., Inc.

System for Geophysical Exploration. A radio transmission system in which shot moment and up-hole impulse are transmitted by frequency modulating the transmitter and communication is transmitted by amplitude modulating the same transmitter, and arranged so that the up-hole signal blocks the system and prevents further transmission.

396—SOIL ANALYSIS

See W. E. Winn and P. F. Dougherty, *Method of Logging Wells;* Class 252.
W. E. Winn and P. F. Dougherty, *Method of Logging Wells;* Class 252.

400—SOIL GAS SAMPLING

U. S. No. 2,411,157. W. J. Fene and G. L. Freas. Iss. 11/19/46. App. 6/8/43. Assign. Government of the U. S.

Means for Collecting Gas Analysis Samples. An electrically controlled gas sampler having a sealed evacuated glass container, an electromagnet which breaks off the tip of the seal and another electromagnet which trips a spring actuated rubber cap to reseal the container.

408—SONIC FLUID LEVEL MEASUREMENT

See A. Wolf and L. G. Cowles, *Well Sounding Microphone;* Class 244.

416—SPECTROGRAPH

U. S. No. 2,413,208. R. B. Barnes. Iss. 12/24/46. App. 4/6/45. Assign. American Cyanamid Co.

Refractometer for Chemical Reactions. Apparatus for detecting changes in refractive index of a liquid by flowing it through a refracting prism, refracting light from a monochromatic source to a photocell which operates a galvanometer and photoelectric relay.

See also W. H. Avery, *Spectrometer Prism Mounting;* Class 196.

420—SPECTROPHOTOMETER

U. S. No. 2,413,080. S. W. Seeley. Iss. 12/24/46. App. 11/16/40. Assign. Radio Corp. of America.

Spectrophotometer. A spectrophotometer for determining the transmission characteristic of a material and in which the light beam is interrupted by a motor driven disk having two equal openings, one of which is covered by the material, the light impulses being compared by a photocell and c-r tube.

U. S. No. 2,413,660. E. I. Stearns, Jr. Iss. 12/31/46. App. 6/1/44. Assign. American Cyanamid Co.

Flickering Beam Spectrophotometer. An integrating spectrophotometer for comparing the reflectance of a sample with that of a standard and having in the optical system a rotating wave-retardation device in the form of a Fresnel rhomb made in two parts with four internal reflections at about 41° each.

428—STRAIN GAUGE

U. S. No. 2,411,139. N. H. Roy and J. L. Bisesi. Iss. 11/12/46. App. 11/18/43. Assign. The Budd Co.

Strain Measuring and Load Controlling Apparatus. A stress measuring apparatus which may be inserted as a link in a load transmitting member and using two carbon pile electrical resistance units in push pull.

432—SUBMARINE LOCATOR

See W. A. Tolson, *Heat Responsive Device;* Class 460.
E. McDermott, *Submarine Detecting Method and Apparatus;* Class 460.

436—SUBMARINE SIGNALING

U. S. No. 2,408,436. W. P. Mason. Iss. 10/1/46. App. 10/24/42. Assign. Bell Telephone Laboratories, Inc.

Multiplex Compressional Wave System. A supersonic transmission or receiving system in which different frequencies are focussed on to different transducers by an acoustic diffraction grating having diffractive elements of decreasing width toward the sides of the grating.

U. S. No. 2,410,066. B. M. Harrison. Iss. 10/29/46. App. 11/11/37. Assign. Submarine Signal Co.

Submarine Signaling. A supersonic echo distance measuring system which transmits a short pulse of changing frequency so as to reduce the effect of random reverberations but gives an easily identifiable reflected signal from a large reflecting surface.

U. S. No. 2,410,067. B. M. Harrison. Iss. 10/29/46. App. 9/23/38. Assign. Submarine Signal Co.

Submarine Signaling. A supersonic echo distance measuring system having a sharply tuned receiver and in which the transmitted pulse is varied over a frequency range which is broader than the receiver frequency band.

U. S. No. 2,411,537. W. D. Goodale, Jr. Iss. 11/26/46. App. 1/28/44. Assign. Bell Telephone Laboratories, Inc.

Submarine Signaling System. A submarine transmission system having two long V-shaped reflecting screens with axes parallel to the line between source and receiver, one screen being above the line to avoid reflections from the water surface and the other screen being below the line to avoid reflections from the bottom.

U. S. No. 2,411,551. W. P. Mason. Iss. 11/26/46. App. 8/19/41. Assign. Bell Telephone Laboratories, Inc.

Radiating System. A multielement piezoelectric directional wave generator having small side lobes and in which the crystal elements are the same length but whose electrode plates increase in width from the outside to the centre of the diaphragm.

U. S. No. 2,411,910. E. E. Truner, Jr. Iss. 12/3/46. App. 5/13/40. Assign. Submarine Signal Co.

Signaling System. A submarine signaling system using a non-rotating directional receiver made up of two resonant magnetostrictive units at right angles with pick-up surfaces spaced one-half wave length apart.

U. S. No. 2,413,462. F. Massa. Iss. 12/31/46. App. 7/30/42. Assign. The Brush Development Co.

Transducer. A piezoelectric hydrophone having two small diaphragms between which the crystal is cemented, the diaphragms being clamped so as not to stress the crystal, and also having a preamplifier in the same housing.

See also J. B. Hays, Jr., *Object Locating System;* Class 108.

L. Batchelder, *Compressional Wave Transmitting and Receiving Apparatus;* Class 484.

E. E. Turner, Jr., *Oscillator;* Class 484.

H. C. Hayes, *Acoustic Wave Generating or Receiving Apparatus;* Class 484.

L. G. Bostwick and J. H. King, *Submarine Signaling Device;* Class 244.

E. E. Turner, Jr., *Magnetostriction Oscillator;* Class 484.

E. E. Turner, Jr., *Means for Producing Mechanical Vibration;* Class 484.

452—THERMAL LOGGING

See A. Frosch, *Well Logging;* Class 516.

460—THERMOMETER

U. S. No. 2,410,317. W. A. Tolson. Iss. 10/29/46. App. 5/1/43. Assign. Radio Corp. of America.

Heat Responsive Device. A heat source locator in which a cam drives a magnetic mirror to spirally scan the area, the mirror motion being detected by magnetic pick-ups which cause a c-r tube beam to synchronously scan its screen, the beam intensity being controlled by the energy received by a thermal cell.

U. S. No. 2,412,165. E. McDermott. Iss. 12/3/46. App. 3/7/42.

Submarine Detecting Method and Apparatus. A method of detecting the heat wake of a submarine from an airplane by scanning the surface of the water both laterally and

fore and aft with pairs of differentially connected directional heat detectors whose signals are automatically corrected for the size of the scanning area.

U. S. No. 2,412,564. F. L. Current. Iss. 12/17/46. App. 7/7/43. Assign. Carnegie-Illinois Steel Corp.

Heat Measuring Apparatus. A thermocouple assembly carried on a metal pipe with a two holed ceramic bushing extending from the end so as to reduce heat transfer from the couple to the pipe.

468—TIME INTERVAL METER

U. S. No. 2,408,727. D. Blitz. Iss. 10/8/46. App. 7/11/44. Assign. Radio Corp. of America.

Means for Circuit Time Constant Measurement. An apparatus for measuring the delay time of circuits or relays by connecting a voltage to the device and to a condenser with resistance in parallel, simultaneously disconnecting the voltage, and indicating the delay in the device by the residual charge on the condenser at the instant the device operates.

See also L. de Forest, *Means and Method for Altitude Determination;* Class 316.

484—TRANSDUCER

U. S. No. 2,408,404. L. Batchelder. Iss. 10/1/46. App. 5/19/33, 3/13/34 and 9/19/38. Assign. Submarine Signal Co.

Compressional Wave Transmitting and Receiving Apparatus. A magnetostriction vibrator having a rectangular radiator mounted on a magnetostrictive strip and having a watertight sealing material between the radiator and the case.

U. S. No. 2,410,112. E. E. Turner, Jr. Iss. 10/29/46. App. 5/8/36. Assign. Submarine Signal Co.

Oscillator. A supersonic vibrator whose radiating element is a figure of revolution with a cross section shaped like an exponential horn and with the driving element at the small end.

U. S. No. 2,410,113. E. E. Turner, Jr. Iss. 10/29/46. App. 3/23/36 and 10/14/37. Assign. Submarine Signal Co.

Oscillator. A supersonic magnetostriction oscillator in which the magnetostrictive material is in the form of a spiral strip with a single turn conductor following one side of the spiral strip and around the inner end, and with the edge of the spiral strip fastened to the radiating plate.

U. S. No. 2,410,329. R. B. Albright. Iss. 10/29/46. App. 9/8/44. Assign. Philco Corp.

Electrical Apparatus. A phonograph pick-up in which the stylus rotates a small coil whose core is part powdered iron and part copper so as to vary the inductance of the coil for operating an F-M receiver.

U. S. No. 2,411,541. H. C. Hayes. Iss. 11/26/46. App. 8/8/36.

Acoustic Wave Generating or Receiving Apparatus. A submarine sound transducer having number of cylindrical recesses filled with a medium of the same acoustical im-

pedance as the surrounding water and with a driving element at the bottom of each recess.

U. S. No. 2,411,911. E. E. Turner, Jr. Iss. 12/3/46. App. 6/18/41. Assign. Submarine Signal Co.

Magnetostriction Oscillator. A polarized magnetostriction oscillator made up of laminations whose sides are the vibrating masses and legs are the elastic elements and having permanent polarizing magnets in the perforations between the legs.

U. S. No. 2,412,536. F. Rieber. Iss. 12/10/46. App. 1/29/44. Assign. Interval Instruments, Inc.

Mechanically Tuned Oscillator. A resonating system having a wire between the poles of a magnet, the end of the wire being fastened to diaphragms carrying a weight and tension on the wire being adjusted by rotating the entire assembly about a horizontal axis.

U. S. No. 2,412,718. R. Dally, F. H. Goldsmith and D. J. Monroe. Iss. 12/17/46. App 8/7/43. Assign. Webster Electric Co.

Recorder. A variable air gap permanent magnet reluctance type phonograph record cutting head.

U. S. No. 2,413,012. E. E. Turner, Jr. Iss. 12/24/46. App. 7/28/38. Assign. Submarine Signal Co.

Means for Producing Mechanical Vibration. A submarine signaling vibrator using magnetostrictive or electromagnetically driven tubes which are flared toward the radiating plate and with the outer side of the plate dome-shaped so that the wave travel path through the material is always $\frac{1}{8}$ wave length.

See also W. R. Koch, *Record Reproducing Circuit;* Class 344.
C. M. Sinnett, *Transducer System;* Class 344.
J. H. Hammond, Jr., *Signaling System;* Class 64.
F. Massa, *Transducer;* Class 436.

488—UP-HOLE IMPULSE RECORDING

See E. M. Shook and R. W. Olson, *System for Geophysical Exploration;* Class 388.

492—VIBROMETER

U. S. No. 2,408,392. D. E. Gillum and C. J. Gallant. Iss. 10/1/46. App. 11/29/41. Assign. North American Aviation, Inc.

Vibrometer. A variable area condenser type displacement vibrometer having pivotally suspended rotor plates.

496—VISCOSIMETER

U. S. No. 2,410,385. S. A. Loukomsky and C. R. Stock. Iss. 10/29/46. App. 4/5/45. Assign. American Cyanamid Co.

Plastometer. A spinning cup viscosimeter in which the drag on a central cylinder is measured with an electric strain gauge and recorded, and an automatic control used to

increase and decrease the speed of cup rotation through a cycle so as to plot a torque-speed curve.

508—WATER LOCATING

U. S. No. 2,410,278. R. F. Farris and J. B. Clark. Iss. 10/29/46. App. 10/30/41. Assign. Stanolind Oil and Gas Co.

Water Locating System. A method and apparatus for locating water sources in a well by removing water from the hole and lowering an apparatus with a number of spaced funnel shaped containers in which accumulation of water is detected electrically as the well is produced.

U. S. No. 2,412,363. D. Silverman. Iss. 12/10/46. App. 1/14/42. Assign. Stanolind Oil and Gas Co.

Well Logging. A method of locating a source of fluid in a well by first stopping production and conditioning the well, then inserting a series of energized electrodes each connected to a recording galvanometer and observing the change in current distribution as production is resumed.

512—WELL SHOOTING

See O. S. Petty, *Measuring Instrument;* Class 376.

516—WELL SIGNALING

U. S. No. 2,411,696. D. Silverman and T. Gilmartin. Iss. 11/26/46. App. 4/26/44. Assign. Stanolind Oil and Gas Co.

Well Signaling System. A repeater located intermediate between the bottom and top of a well for an electrical drill stem signaling system in which the drill stem and earth form a single turn secondary on a toroidal transformer and which picks up the signal from electrodes and retransmits it through a toroidal transformer at a different frequency.

U. S. No. 2,412,575. A. Frosch. Iss. 12/17/46. App. 7/26/41. Assign. Standard Oil Development Co.

Well Logging. An apparatus for simultaneously logging two quantities over a single cable by having a carrier wave oscillator in the well, the frequency being varied by one quantity and the amplitude varied by the other quantity.

See also C. B. Aiken, *Compensating Means for Electrical Borehole Apparatus;* Class 116.

520—WELL SURVEYING

U. S. No. 2,413,005. G. A. Smith. Iss. 12/24/46. App. 10/23/41. Assign. Sperry-Sun Well Surveying Co.

Well Surveying Instrument. A deviation recorder using a pendulum and a magnetic compass each with luminescent or radioactive material which marks a photographic record disk when the instrument is held at rest for a time.

See also W. H. Emerson and D. Hering, *Well Surveying Instrument;* Class 192.

DISCUSSIONS AND COMMUNICATIONS

THE COMMITTEE ON GEOPHYSICAL SCIENCES

Notice has just been released from Washington of the organizational meeting of The Committee on Geophysical Sciences of The Joint Research and Development Board (Army and Navy) and of the appointment of Dr. Roland F. Beers, Dallas, Texas, as Chairman of the Committee.

The objective of The Joint Research and Development Board is to coordinate all research and development activities of joint interest to the War and Navy Departments in order that they will establish and carry out a strong, unified, integrated and complete research and development program in the field of national defense. The Board will not attempt to control the administration of research and development activities, but will leave such administration to agencies within the War and Navy Departments charged with such responsibilities by law or intra-departmental directive. The JRDB operates within its jurisdiction as an agency of the Secretaries of War and the Navy.

Its membership consists of Dr. Vannevar Bush, as Civilian Chairman, General J. L. Devers, Commanding General of Army Ground Forces, Honorable W. J. Kenney, Assistant Secretary of the Navy, Admiral D. C. Ramsey, Vice Chief of Naval Operations and General C. Spaatz, Commanding General Army Air Forces.

The Committee on Geophysical Sciences is established by JRDB to assist the Board in carrying out the provisions of its charter in the Departments of scientific research lying within the geophysical sciences. These include:

Physics of the Upper Atmosphere. This is the region where cosmic rays and ultra-violet light are of considerable significance and in which long-range rockets and possibly Jet-planes will attain great speeds.

Meterology of the Lower Atmosphere, where the weather is of more significance and in which all ordinary flying is now done. This is the area in which thunderstorms and other electrical phenomena create hazards to flight and difficulties in the control of guided missiles.

Geomagnetism is the phenomena of the earth as a great magnet which produces the north and south magnetic poles and the variations in both direction and strength of the magnetic lines of force surrounding the earth.

Geology, the study of the earth, its structure and its surface phenomena, of mountains and minerals, sediments and fuel resources.

Hydrology, The study of the water content of the earth both in the atmosphere, in the ground, and in the sea. Water is the most significant single factor affecting life on this planet.

Oceanography, is the study of the great mass of water covering more than 72% of the earth and within which are both physical and biological phenomena of great significance to both the Army and the Navy.

Seismology, the study of earthquakes and the movements of the crust of the earth which cause them. Next to war itself earthquakes and tidal waves cause greatest human disaster.

Geodesy, which is the study of the shape of the earth. The fact that the earth is not a perfect sphere and is slowly changing its shape is of increasing significance in modern long-range navigation and in long-range missile control. The science of Cartography is concerned with the many different methods and devices for showing the true relation of features of the earth's surface. The air navigator

requires a different map from that used by the sea navigator and both require weather maps. The kinds and special uses of maps are legion.

These are only a few of the specilaized fields of science and research which are now not only useful but essential to modern war.

The members of the Committee on Geophysical Sciences of The Joint Research and Development Board are:

Dr. Roland Beers, formerly of the faculty of Massachusetts Institute of Technology and a field geophysicist of wide experience. Chairman.

Dr. Carl G. Rossby, Director of the Meteorological Institute, University of Chicago.

Dr. Chester R. Longwell, Chairman, Department of Geology, of Yale University.

Samuel B. Morris, General Manager and Chief Engineer of the Department of Water and Power, Los Angeles, California, and former Dean of Engineering at Stanford University.

Rear Admiral R. O. Glover, Hydrographer of the U. S. Navy.

Captain Howard B. Hutchinson, Aerologist with the Office of Naval Research, U. S. Navy.

Colonel B. G. Holzman, a member of the staff of the Deputy Chief of Air Staff for research and development, who conducted weather research in Laborador, Greenland, and England prior to the invasion of Normandy.

Colonel D. N. Yates, Chief Air Weather Service, who served as staff weather officer for General Eisenhower and General Spaatz during the European Operations.

The Committee will coordinate the research and development activities of the Army and Navy which require the specialized techniques of the many geophysical sciences. It will be assisted by a number of panels composed of scientists, engineers, and consultants drawn from government, industrial and academic institutions.

A BIOLOGICAL PROOF OF PETROLEUM EMANATIONS

By V. Thyssen-Bornemisza*

Separate from "Die Naturwissenschaften" 1943
31 Jahrg. Heft 25/26
(Springer-Verlag, Berlin W 9)

"It cannot be denied that the chemical-physical structure of the near surface layers of the earth's crust reflect their physical characteristics and chemical composition in the plant life that covers them,[1] in spite of the many retractions and changes which the science of Botany has had to make in this matter. The fact that many plants and plant components can store up metals has been recognized and utilized by miners and geologists, in that they correlate the occurrence of certain trace elements such as gold and lead in certain plants with corresponding mineral deposits.[2] On the other hand the science of Applied Geophysics has long sought a useful method for proving and possibly determining quantitatively the presence of hydrocarbons which have migrated through the overlying formations to the earth's surface.[3] Hydrocarbons are found almost universally in

* Seismos Company, Hanover, April 3, 1943; translated by R. A. Geyer.

[1] St. V. Thyssen-Bornemisza, "Beitr. angew. Geophysik," 10, 35 (1942).

[2] K. Rankama, "Geol. Rdschau," 32, 573 (1941).

[3] St. V. Thyssen-Bornemisza, "Oel u. Kohle," 38, 555 (1942).

the earth's crust near the surface layers usually irrespective of whether or not an appreciable deposit of oil exists in the vicinity. For example, methane is formed as the result of the decomposition of organic matter. Evidence of the actual effects of mineral deposits is therefore generally either obscured or cannot be proved.

"S. Strugger and C. Rouschal working in cooperation with the Botanical Institute of the Veterinary University in Hanover were successful in obtaining a conclusive plant biological reaction from the emanations of crude oil found in North Germany. The well-known work of Molisch[4] and other authors[5,6] was extended regarding the effect of very minute quantities (0.005–0.0005%) of ethylene and other similar substances on the sprouts of legumes and other plants. Experiments conducted with methane, hydrogen gas, and other saturated hydrocarbons which are present in the earth and the biosphere yielded negative results. However, impurities in the air or the soil from quantities of petroleum gases resulted in such characteristic manifestations as retardation of growth, increased growth in thickness of the branches and epinasty (leaves grow in such a manner that the edges curve downward) of the leaves. These proven specific reactions must be attributed to the presence of ethylenes or other olefines in crude oil[7] but at the present time have not been definitely substantiated in all cases. The investigations are continuing."

[4] H. Molisch, "Der Einfluss einer Pflanze auf die andere," Jena, 1937.
[5] W. Grocker, "Proc. Amer. Philos. Soc.," 71, 5 (1932).
[6] D. Michener, "Amer. J. Bot.," 25, 711 (1938).
[7] E. Blumer, "Die Erdoellagerstaetten," S. 22, Zuerich, 1922.

BOOKS AND WORLD RECOVERY

The desperate and continued need for American publications to serve as tools of physical and intellectual reconstruction abroad has been made vividly apparent by appeals from scholars in many lands. The American Book Center for War Devastated Libraries has been urged to continue meeting this need at least through 1947. The Book Center is therefore making a renewed appeal for American books and periodicals —for *technical and scholarly books and periodicals in all fields* and particularly for *publications of the past ten years*. We shall especially welcome complete or incomplete files of GEOPHYSICS.

The generous support which has been given to the Book Center has made it possible to ship more than 700,000 volumes abroad in the past year. It is hoped to double this amount before the Book Center closes. The books and periodicals which your personal or institutional library can spare are urgently needed and will help in the reconstruction which must preface world understanding and peace.

Ship your contributions to the American Book Center, c/o The Library of Congress, Washington 25, D. C. freight prepaid, or write to the Center for further information.

LABORATORY OF APPLIED GEOPHYSICS AND GEOCHEMISTRY

The Pennsylvania State College, State College, Pennsylvania

A laboratory of applied geophysics and geochemistry has recently been established at the Pennsylvania State College under the direction of Dr. Sylvain J. Pirson. The program of work includes both resident instruction and fundamental as well as practical researches in the development of new mineral resources.

For the first time in the history of American academic institutions a course in geochemistry will be given at Penn State. A beginning was, however, made by the Graduate School of the Department of Agriculture in Washington, D. C., which introduced a course in the subject in 1943 under the charge of Dr. Chambliss.

Geochemistry, "stricto sensus," is not a well known field in the U. S. A. and in this respect we are possibly 20 to 25 years behind the Russians who have produced outstanding modern geochemists such as W. I. Vernadsky, A. E. Fersman, E. S. Federov and others. Accordingly, the field of work should be defined and delineated in order that confusion may not exist with the meaning of the word "geochemistry" when used "lato sensus."

In its strictest sense, geochemistry is the study of the origin, occurrence, association, abundance, migration, distribution, dispersion and accumulation of atomic elements within the geosphere including the atmosphere. Since the earth is derived from cosmic matter, it is natural that the basis for a chemical understanding of the earth's atomic processes should be based on astrophysical and astrochemical concepts. The origin of matter and its evolution in the earth over astronomic time is the special field in geochemistry. The border line fields of chemical and atomic physics provide the fundamental laws for this study: nuclear and electronic configurations of the atoms, atomic numbers and weights, atomic and ionic radii, coordination numbers, crystal structures, energies and lattices, etc., explain the paragenetic relationships of the 92 geochemical and of the possible transuranic elements.

The pragmatic aspect of geochemical sciences is not neglected in the new courses. The application of the principles of geochemical processes and associations is the basis of the long range forecast of future reserves of essential industrial elements. An understanding of these principles will help to conceive, formulate and develop new technological means for prospecting and delineating hidden mineral reserves. The method thus far best known in this country is geochemical prospecting for oil and gas fields, the principles of which are still taken as preposterous by much of the practical geological profession notwithstanding some remarkable successes and a commendable score in the ratio of exploration successes to failures.

Compared to geochemical exploration for oil and gas, exploration for ore deposits has made but a timid start. The fundamental concept at the basis of these methods of approach is the ionic diffusion of elements to nearsurface layers where their abnormal presence may be revealed by micro analytical tests of soils, ground water and vegetation. Broad geochemical provinces may thus be outlined in which chemical concentrates (zonal distribution patterns), belts, zones, nodes, etc., may be delineated and the probable existence of hidden mineral treasures may be ascertained.

The standard methods of geophysical prospecting for minerals are not neglected in the Penn State program of study and research, nor their most recent developments. A program of airborne magnetometer survey of part of the State of Pennsylvania in cooperation with the U. S. Geological Survey has been initiated, the purpose of which is to study the manner in which the parallel structures visible in the Allegheny Mountains may be traced into the Appalachian geosyncline where deep oil and gas structure are expected to be found in close association with uplifts within the precambrian basement rocks.

REVIEWS

SPECIAL REVIEWS COMMITTEE

THOMAS A. ELKINS, Gulf Research & Development Co., Pittsburgh, Pa., *Chairman*
R. A. GEYER, Humble Oil and Refining Co., Houston, Texas
NORMAN RICKER, Carter Oil Co., Tulsa, Oklahoma
D. C. SKEELS, Standard Oil Co., of New Jersey, New York, N. Y.

The resolving power of magnetic observations, by Irwin Roman. American Institute of Mining and Metallurgical Engineers Technical Publication No. 2097 (November 1946). 18 pages. This appeared in "Mining Technology," volume 10, number 6 (November 1946).

The title of this paper is misleading, since, although resolving power (i.e., the ability to separate nearby anomalies) is discussed, the greater part of the paper is a general account and comparison of the three types of magnetic anomalies now observable directly, since the advent of the airborne magnetometer. These are the classical anomalies in the horizontal and vertical magnetic fields and the new "total" anomaly, which is defined as the excess of the magnitude of total magnetic intensity over the magnitude of the normal field.

Graphs of the horizontal, vertical, and total anomalies are presented for the following types of magnetic "structures": the line pole, the line dipole, a pair of positive line poles, all lying east-west magnetically. Also given are total and vertical intensity maps for two observed anomalies, whose geographical locations are omitted without any explanation.

The author, on the basis of the special cases presented in this paper, as well as on more elaborate calculations (not described in detail) for distributed bodies, and on his general experience over a number of years, deduces the following conclusions:

1. In the northern magnetic hemisphere, the total anomaly for a positive disturbing body (that is, one due to a south-seeking pole) is offset to the south of the body.

2. The resolving power of magnetic observations decreases rapidly with the depth of the body.

3. The horizontal anomaly may be used for verification of predictions but has questionable identification value.

This paper by Dr. Roman, of the U. S. Bureau of Mines, is well worth reading for its ingenious analysis.

THOMAS E. ELKINS

Questions actuelles de géophysique théorique et appliquée (Present day questions of theoretical and applied geophysics), by Edmond Rothé. Paris, Gauthier-Villars, 1943. viii+427 pages.

Although the emphasis is on recent theories and developments, this posthumous work of the distinguished French geophysicist is essentially a textbook of theoretical and applied geophysics, which supplements rather than replaces his earlier book, "Les méthodes de prospection du sous-sol" (Paris, Gauthier-Villars et Cie., 1930). Its scope can be gathered from the chapter headings:

I. Geophysics, the physics of the earth. II. Gravitation and gravity. The gravity anomalies on the globe. III. New procedures for studies of gravity. Gravimeters and

gravity balances. IV. Isostasy and the variations of shore lines. V. Radioactivity in the earth's crust. VI. Volcanology. VII. Seismology. VIII. Interpretations and causes of terrestrial magnetism.

From the bibliographies at the ends of the chapters, it seems that very little material published after 1939 has been considered. Consequently, the book is not as up to date as its imprint would indicate and much recent American work is completely ignored. However, the resulting concentration on French, German and other Continental European work has the advantage for American readers of bringing to light many interesting studies which might be unknown to or neglected by them. As the only recent textbook now available on general geophysics, it is a valuable addition to geophysical literature.

THOMAS E. ELKINS

Der Gesteinsmagnetismus; seine Beziehungen zur den Erscheinungen des Ferromagnetismus und zum erdmagnetischen Feld (The magnetism of rocks; its relations to the phenomena of ferromagnetism and to the earth's magnetic field), by Hans Haalck. Leipzig, Akademische Verlagsgesellschaft Becker & Erler Kom-Ges., 1942: Lithoprint edition published by J. W. Edwards, Ann Arbor, Michigan, U. S. A., 1945. viii+90 pages.

With the advent of the airborne magnetometer renewed interest in magnetic geophysical prospecting methods is evident. A large number of references are available in the literature dealing with the interpretation of magnetic data in terms of the many factors responsible for the magnetic properties of rocks. However, until the publication of Haalck's book, the material that has appeared in recent years has not been synthesized and evaluated. The presence of 147 references dispersed throughout this book should prove to be a valuable aid to those wishing to investigate further some of the characteristics of rock magnetism which are presented. Reference is also made to an important bibliography dealing with the literature of this subject available prior to 1900 to be found in S. Günther's *Handbuch der Geophysik*, Volume I, published in Stuttgart in 1897, pp. 569–588.

Haalck in the introduction stresses the inherent difficulties and limitations of the experimental method as a means of studying the magnetic characteristics of rocks because it is so difficult to know as well as to preproduce in the laboratory the exact conditions which occur in nature.

The subject of rock magnetism is subdivided into five sections, namely:

A. The physical basis for the magnetic properties of rocks which includes discussions on:
   (a) our concepts of the phenomenon of ferromagnetism,
   (b) the minerals responsible for rock magnetism,
   (c) the magnetizing forces,
   (d) pronounced differences in the magnetic properties of rocks as a function of the shape and position of geologic formations,
   (e) the effect of temperature on ferromagnetic manifestations, and
   (f) the distribution of temperature within the earth's crust.

B. The development of rock magnetism including:
   (a) the origin of rock magnetism,
   (b) the magnetization of geologic formations in the upper portion of the earth's crust,

(c) the influence of geologic history on the magnetic properties of rocks after their initial magnetization,
(d) the effect of the time or "aging" factor on the magnetic characteristics of rocks.

C. The magnetic properties of individual rock specimens including a discussion of:
(a) the experimental determination of the susceptibility of rock specimens,
(b) the problem of the magnetization of core samples, and
(c) the direction of magnetization of rock specimens and pottery, and the question of the direction of the earth's magnetic field during the past.

D. The direction and magnitude of magnetization of geologic formations of both local and regional significance involving a discussion of:
(a) anomalies in the earth's magnetic field caused by the magnetic properties of rocks,
(b) theories dealing with the determination of the magnetization of geologic formations by magnetic fields existing near the earth's surface,
(c) specific examples of the magnetization of geologic formations,
(d) possible causes of abnormal or anomalous magnetization of geologic formations.

E. The relationship of rock magnetism with the earth's magnetic field including a discussion of:
(a) the percentage of the total earth's magnetic field that is concentrated in the earth's crust,
(b) possible relationships between rock magnetism and secular variation,
(c) the local changes in rock magnetism with time.

Haalck concludes his book with an attempt to summarize our present knowledge, both empirical and laboratory, of the magnetic characteristics of rocks as interpreted primarily in terms of currently accepted ferromagnetic theory.

The major points of his 14 conclusions as to the present status of our knowledge of rock magnetism may be listed as follows:

1. The most important contributor in the mineral form to the magnetic properties of rocks is magnetite. However, magnetite crystals do not all exhibit the same magnetic properties and as a result the magnetite content alone is not the deciding factor in determining the magnetic properties of rocks. Petrographic characteristics, physico-chemical considerations and the geologic history and evolution of the rocks containing magnetite also play an important part in determining their magnetic properties.
2. The strength of the induction field decreases slowly with increasing depth because of increasing temperature, and the Curie point (ca. 600 degrees) is reached in the continental areas at approximately 20 or 30 kilometers and beneath the major oceans at possibly twice this depth. After the Curie point has been passed the induction field drops rapidly to a negligible value.
3. The total rock magnetism of the earth's crust does not exceed 15 per cent of the total earth's magnetic field. It should be noted that this value given by Haalck is much larger than the five per cent figure usually stated in recent literature. However, he does not elaborate in the text as to the reasons for reaching this conclusion.
4. The direction of rock magnetism is the same as that for the earth's magnetic field except in a very few cases.
5. None of the magnetic anomalies of a regional character have as yet been correlated with regional geologic features. Haalck attempts to explain this on the

basis that the causes of major regional anomalous areas are dependent chiefly on the differences in temperature in the deeper zones for the given areas.

6. It is probable that the causes of secular changes of the earth's characteristics, either entirely or in part, must be sought for in the temperature changes which occur in the earth's crust at depths involving the Curie point. However, the empirical investigation of the regional characteristics of secular variations has not yet reached the point where any definite conclusions can be made.

However, it is interesting to note that Vestine, et al.[1] in a recent paper describe the geomagnetic secular variation during the past four decades and also present a preliminary interpretation of its origin together with that of the main earth's magnetic field. They believe that the "way may then be left open to explain the main field and its secular change on the basis either of thermoelectric forces or piezoelectric forces associated with stresses existing within the supposed crystalline mantle. The stresses or variations in temperature must be subject to rapid variation with time as compared with the slow processes, such as mountain building, evinced in the earth's crust."

R. A. GEYER

[1] Vestine, E. H.; LaPorte, L. and Cooper, C., Geomagnetic secular change during past epochs, Transactions, American Geophysical Union, vol. 27, pp. 814–822 (1946).

Studies in the distribution of gravity anomalies in north-east Honshu and the central part of the Nippon Trench, Japan, by Naoiti Kumagai. Japanese Journal of Astronomy and Geophysics, volume 17, pages 477–553 (1940).

Kumagai presents a detailed quantitative evaluation of the apparent relationships between the areal distribution and magnitude of isostatic gravity anomalies and certain geologic and seismic characteristics observed in the central part of the Nippon Trench and in north-east Honshu. The mathematical exposition of his ideas necessitates the use of more than 70 formulae and 22 tables. In addition to the 26 land and 15 marine gravity stations which constitute the basis for his analysis he has also drawn upon the facts and ideas found in 48 geodetic, geologic and seismic references including those of Heiskanen, Helmert, Vening Meinesz, Cassinis, Lambert, Bowie and others.

A two-dimensional analysis in which the curvature of the earth's crust is neglected is made of the distribution of the free-air anomalies at sea and Bouguer anomalies on land, as well as of the land and submarine topography. In addition, isostatic reductions are calculated for various depths of compensation based on Pratt's isostatic hypothesis and the most probable depth is chosen. However, it should be noted that the isostatic anomalies for the most probable depth are very large indicating a pronounced lack of isostatic equilibrium. For example, the departure from complete compensation, without regard to sign, for the land and sea areas as a unit averages more than 100 per cent of the computed anomaly. Kumagai discusses this situation as follows:

"On the coastal region over the Japan Sea the calculated anomaly appreciably exceeds the observed anomaly. When the signs are disregarded, we see that below the land area, on an average 61 per cent of the calculated anomaly is uncompensated; below the Pacific area, the average is 164 per cent, which is 2.7 times the above mean departure below land. Below the total areas of land and sea the average is 113 per cent."

These large isostatic anomalies are closely related to certain geologic characteristics of this area and may be interpreted as the resultant of the density deficiency attributed to the sedimentary formations, and the excess in density caused by the under lying known batholith and the postulated batholith or cryptobatholith. The vertical thickness of the sedimentary formations and the depth to the bottom of the batholith using sea level as a reference plane are calculated from the distribution of the anomalies. A clear concept of these relationships may be seen in Fig. 1-A. This figure is a composite of several presented in the paper and attempts to summarize the pertinent character-

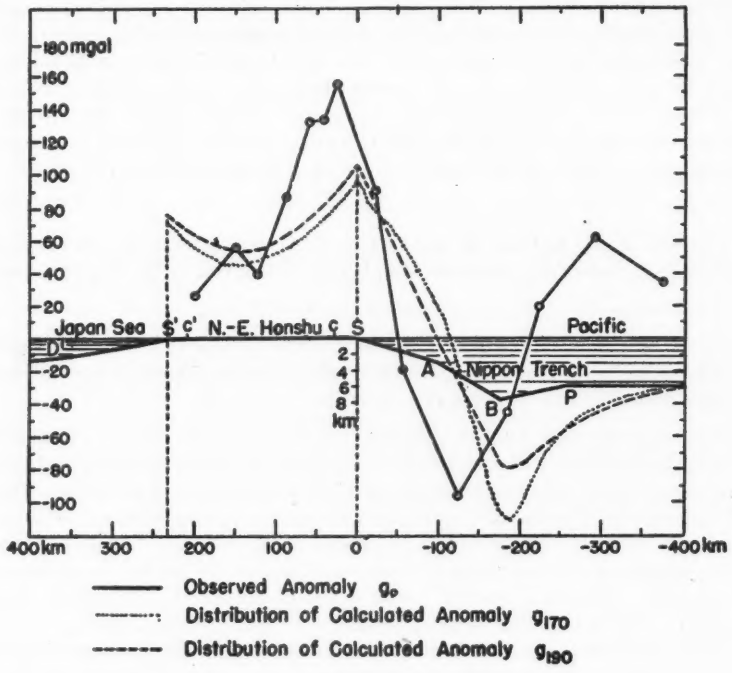


FIG. 1-A

istics of the observed and calculated anomalies and their relation to the geologic characteristics of the area.

Perhaps the most striking feature illustrated in Fig. 1-A is the marked discrepancy between the observed anomalies and the calculated ones reflecting in large measure the pronounced departure from complete compensation. In addition, it should be noted that over the Pacific floor beyond the deepest part of the trench (ABP) the observed anomalies are positive whereas the calculated ones are negative. On the other hand, over the coastal region (SAB) of the Japan Sea the calculated anomaly exceeds the observed anomaly to a marked degree. A quantitative discussion of the departures from complete compensation has been discussed in the second paragraph.

If the variation of the calculated anomaly g_{170} over the continental shelf and the trench is compared with that of the calculated anomaly g_{190} the following differences are

evident: (a) the largest positive anomalies for both assumed depths of compensation occur at S and over the shelf (SA), whereas the largest negative values are found over the deepest part of the trench (ABP). However, the plot of g_{170} is convex toward the Pacific Ocean side whereas that of g_{190} is nearly linear. In addition, the greatest negative value for the g_{170} curve exceeds that for the g_{190} by 31 miligals. Kumagai believes that these differences are caused by the fact that the vertical attraction of either of the two long prisms of the earth's crust assumed in the compensation calculations, one having positive density and the other some negative density portions, is numerically greater

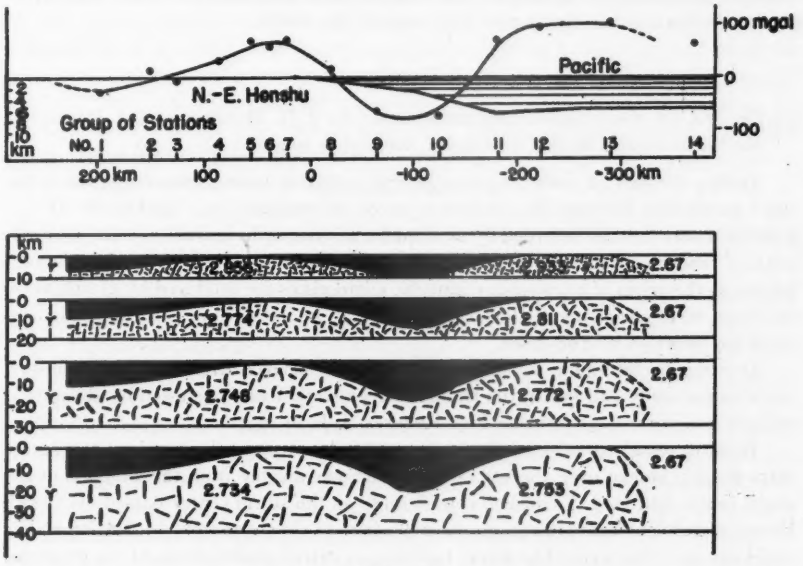


FIG. 1-B

for points above the prism than the vertical attraction caused by the corresponding masses which are compensating these prism masses. The comparative profiles plotted in Fig. 1-A also yield an indication as to the magnitude of the quantitative differences that may arise in calculating isostatic compensation using several different sets of assumptions and approximations.

Fig. 1-B illustrates the relationship between the isostatic anomaly computed for a depth of compensation of T = 170 kms and the variations in thickness of the sedimentary formations overlying the batholith and cryptobatholith, assuming several different density values in combination for both of these igneous intrusions. The density value of 2.43 assumed for the sedimentary formations is appreciably lower than the value generally used in calculations of this type, namely, 2.67. These values for the underlying batholiths vary from 2.734 and 2.753 to a maximum of 2.856 and 2.933. As would be expected, the thickness of the sedimentary formations in the two basins decreases from approximately 12 and 20 kms for the case where the density of the intrusions is a minimum to 8 and 10 kms when the maximum density values are used.

It should be noted that the major positive and negative isostatic gravity anomalies

coincide remarkably well with zones in which earthquakes frequently occur. Kumagai interprets this coincidence as evidence that the cause of these earthquakes is closely related to the processes involved in isostatic adjustment. Another interesting feature of these isostatic anomaly zones is their marked similarity to those observed by Vening Meinesz in the Java-Sumatra and Java Trench areas.

Some may disagree with a number of conclusions and interpretations made by Kumagai in his study of the distribution of gravity anomalies for this region. However, several of the quantitative methods that he used in synthesizing and analyzing the gravitational, geological, topographical and bathymetrical data can be readily applied to similar studies in other continental shelf areas of the world.

R. A. GEYER

(a) *The problem of microseisms and ocean storms*, by J. B. Macelwane, S. J. Bulletin of the Seismological Society of America, volume 36, pages 81–82 (1946).

During the past 40 years there was general confusion among seismologists as to the exact correlation between the various types of microseisms, i.e., "practically all . . . types of waves that are recorded by earthquake seismographs and are not due to earthquakes," and meterological storms. By 1937, there were three schools of thought pertaining to the origin of microseisms; namely, microseisms are produced by a) surf along the coast, b) at the center of storms at sea, and, c) in certain types of frontal disturbances anywhere on land or at sea.

In order to determine which theories might be correct after the old established methods for study had failed, the tripartite type station was suggested by the author and put into operation by Father E. J. Ramirez, S. J., in 1937.

Ramirez found (1) large microseismic amplitudes produced by hurricanes or severe extra-tropical storms over the sea, only; (2) the waves came from the direction of the storm center and they diminished considerably as the storm center passed over land. He was not able to locate the geographical position of the storm from one station and he could not say "that every hurricane, typhoon, or extra-tropical storm at sea generates this type of microseism and that they can be recorded and recognized as such at any tripartite station." This was later established completely and to the satisfaction of most seismologists by the United States Naval Microseismic Research Project established in 1943.

(b) *A description of the instruments used to record microseisms for the purpose of detecting and tracking hurricanes*, by W. F. Sprengnether, Jr. Bulletin of the Seismological Society of America, volume 36, pages 83–87 (1946).

In making an exhaustive study of the types of microseismic waves produced by various meteorological conditions, it was decided by experts of the U.S. Navy Hurricane-Microseismic Research Project that instruments designed for this particular work must be used in preference to ordinary teleseismic equipment.

In developing a special electromagnetic seismometer for the project, it was required that the instrument be very sensitive to recording these special type waves and still be of sufficiently simple design to be operated by personnel with only limited training in seismology. The seismometer consists of three essential elements; namely, the pendulum assembly, the coil magnetic unit, and the damping magnetic unit. Because a special bar holds the entire boom system rigid in its correct position there is little danger

of damage in assembling this unit. The current obtained from the magnetic coils is carried through the hinges of the boom assembly thereby eliminating the problem of delicate wires and also the necessity for providing a compensating force in determining the instrumental constants. The usual adjustable permanent magnets are employed, providing for variable damping.

This seismometer comes equipped with all of the essentials for determining its static magnification which is approximately 2500 for a period of six seconds.

A special three component recorder with a synchronous drive motor having a power rating of twelve watts was developed to operate with the electromagnetic seismometers. The three drums are mounted on a single shaft which, because of a special motor drive to the lead screw, produces greater separation between lines as the drum speed is increased to 288.5 mm. per minute. The recorders which are entirely enclosed to make them light-tight have both a special panel at one end of the assembly for complete control of the operation of the lights, motors, etc., and special screws for focussing the lights without interrupting operation.

(c) *Microseisms and ocean storms*, by Marion H. Gilmore, Bulletin of the Seismological Society of America, volume 36, pages 89–119 (1946).

As an introduction to his paper, Mr. Gilmore presents the problem of the origin and nature of microseisms by reviewing investigations made during the previous forty years. These were essentially general correlations of microseismic amplitudes with prevailing meteorological conditions either in the vicinity of the particular observatories or over the oceans.

Because of the success obtained by Ramirez in 1938 with an experimental tripartite station at St. Louis in studying these problems, the U.S. Navy began a very thorough investigation in 1943 with the object of determining to what extent microseismic recordings could be used in detecting and tracking hurricanes. The tripartite station, consisting of three stations set approximately half a wave length apart (several kilometers) in a triangular pattern, for the first time enabled a reliable measurement of the direction of the microseismic wave motion to be made. It seemed no longer necessary to depend entirely on amplitude correlations.

By the time the 1944 hurricane season arrived in the Caribbean a tripartite station was operating at Guantanamo Bay, Cuba. Unfortunately, only one instrument was functioning when the first hurricane passed near the observatory and no azimuth for the storm could be obtained although good correlation was observed between the position of the storm and the amplitudes of the microseisms. For the succeeding storms that year very good bearings were obtained for the entire path of each storm and it was interesting to note that this method detected one of these storms two days before it was announced by the United States Weather Bureau and the Navy.

Because the work in 1944 definitely showed the possibilities for detecting, locating, and tracking atmospheric disturbances by seismographic methods, it was decided to install additional tripartite stations at Richmond, Florida and Roosevelt Roads, Puerto Rico for the 1945 season. Also, central recording was provided at each station which greatly simplified and expedited analysis of the records which was necessarily urgent.

Again this method proved to all concerned that it was a valuable asset in storm detection as it gave excellent results not only with respect to bearings but also exact positions of the storms. It also proved extremely valuable in that it could operate effectively about 2,000 miles from a severe storm center.

The study provided the following outstanding results: (1) the two to seven second period microseismic waves originate in some manner near the atmospheric disturbances; (2) the approximate location of hurricanes and extra-tropical lows may be determined by this method; (3) a more thorough knowledge of geological structure under the oceans is obtained; and (4) microseisms may at times be produced over land as well as water.

The research project was successful in solving many problems and it is encouraging to note that it is to be continued and expanded.

(d) *Microseisms classified according to type of storms*, by Marion H. Gilmore. Transactions, American Geophysical Union, volume 27, pages 466–473 (1946).

An investigation of the types of microseisms recorded in the Caribbean by the personnel of the U.S. Navy's Hurricane-Microseismic Research Project during the years 1944 and 1945 reveals many characteristic waves which may be readily identified with specific meteorological disturbances either tropical or extra-tropical. Mr. Gilmore gives an excellent pictorial survey of microseisms caused by (1) hurricanes, at various distances from the recording instruments, over sea and land, illustrating (a) short irregular wave groups as the storm is developing over water, (b) gradual formation of regular wave groups when the storm is well-developed and is still over water, (c) a pronounced decrease in amplitude as the hurricane passes over land, and (d) a sharp rise in activity as the hurricane turns again to the sea; (2) thunderstorms, which are very similar to those produced by a hurricane except the waves are of smaller amplitudes, short period, and very short time duration ($\frac{1}{4}$ day instead of days as in the case of hurricanes); (3) cold fronts and high winds, which are in general irregular long period waves producing a rapid change in wave characteristics from the normal microseisms.

A very informative summary of the microseismic characteristics produced by the various meteorological disturbances showing type, period, amplitudes, and form of waves along with the duration of these storms is tabulated by the author. As stated by the author this is the first attempt to correlate such data and the correlation will undoubtedly be improved and made more complete as additional information becomes available.

L. M. MURPHY

"Report on 1946 Activities of the Associate Committee on Geophysics of the National Research Council of Canada" (16 pp.).

The first annual report of the Associate Committee on Geophysics of the National Research Council of Canada has been published. This committee was authorized by the National Research Council of Canada and in part takes the place of the National Committee for Canada (of the I.U.G.G.) in the Department of Mines and Resources which had been inactive during the war. Rather than revive this committee, the chairman, Mr. Ogilvie, arranged that the National Research Council be asked to take over his committee and combine it with the Associate Committee on Geophysics. It is planned that the active members of both will be included in the reorganized Associate Committee on Geodesy and Geophysics. It should also be noted at this point that a Geophysical Committee of the Geological Division of the Canadian Institute of Mining and Metallurgy also exists. However, it deals with many matters non-scientific in nature such as assessment laws, custom and tax rate, methods and procedure and professional ethics, and, therefore, does not overlap with the Associate Committee.

Steps have been taken to hold open meetings and to begin the publication of a bibliography. Many problems have been found which deserve investigation and some progress has been made towards solving them. This report deals with the open meeting of January 23, 1947, and lists the names and positions of the 20 members of the committee. It also includes a statement of the purpose of the committee, a listing of its individual fields of research and their respective sub-committees, together with a review of the status of the various projects which have been organized.

For some reason not explained in the report the decision was made at the first meeting when setting up the sub-committees to omit, for the present, the geophysical fields of hydrology, meteorology, vulcanology and oceanography. These fields constitute very active and important sections of the American Geophysical Union, which can be considered as the American counterpart of this Canadian Committee. Six sub-committees were established for those fields for which it was agreed that research would be actively pursued. These sub-committees are listed as follows:

Sub-committee on Terrestrial Magnetism and Magnetic Methods of Prospecting (Magnetic Sub-committee)

Gravity Sub-committee

Sub-committee on Electrical and Electromagnetic Methods of Prospecting (Electromagnetic Sub-committee)

Seismic and Acoustic Sub-committee

Sub-committee on Tectonophysics and Miscellaneous Geophysical Methods (Tectonophysics Sub-committee)

Sub-committee on Electrical Phenomena of the Earth (Ionosphere Sub-committee)

Eight projects either have been proposed or are under investigation in the field of geomagnetism. These projects are listed as follows:

Project M 1: Development of an airborne magnetometer for use in Canada and survey of parts of the Precambrian Shield

Project M 2: The design of a simple and cheap magnetic variometer

Project M 3: The elimination of the necessity for continuously recording magnetic variations in field surveys on mining properties

Project M 4: The compilation, correlation, and interpretation of magnetic surveys made by prospecting companies on mining properties

Project M 5: Additional magnetic data from the Canadian Arctic

Project M 6: The investigation of the magnetic properties of a series of Canadian rocks

Project M 7: Magnetic observations by ground and air on Exercise Musk-ox

Project M 8: The publication of a set of theoretical magnetic anomaly curves as an aid to interpretation

Project M 1 has made considerable progress. Dr. Boyle of the N.R.C. was able to obtain three MAD sets from the U.S. Navy and has arranged to have these airborne magnetometers available to the Department of Mines and Resources for the summer of 1947. Arrangements were also made by the Department for a U.S. Geological Survey crew and magnetometer to visit Canada. Their plane and equipment were examined by about 75 mining men and magnetic surveys of a portion of the Sudbury Basin and of Louvicourt Township were made. These surveys will be published by the Geological Survey of Canada in cooperation with the U.S.G.S.

Another interesting project is M 4 made possible by the cooperation of many mining companies supplying detailed magnetic surveys of their properties. They have supplied plans of magnetic readings for several hundred properties and as a start the

Bourlamaque district was chosen and the magnetic data available for five townships have been compiled and contoured. They will be compared with the geology and are now being prepared for publication by the Geological Survey of Canada. The committee has obtained a grant of $3,000 from N.R.C. for drafting costs and other expenses of this trial compilation.

A grant of $2,500 has been obtained from the N.R.C. to enable Dr. Gilchrist to carry out the required measurements on suites of rocks he is obtaining from mining companies for Project M 6. Nearly all the remaining projects are either in the formative stage or have suffered from lack of personnel and/or equipment. It is hoped that this situation will be remedied in the near future.

Three gravity projects which are listed as follows have been outlined:

Project G 1: The purchase of a gravimeter by the Dominion Observatory

Project G 2: The construction of a pendulum apparatus with a crystal controlled timing device

Project G 3: The extension of astronomic observations to parts of Canada already covered by geodetic triangulation

A Mott-Smith gravity meter was purchased and used last summer by the Dominion Observatory at the request of the Geological Survey for aid in the interpretation of geological structure by conducting a traverse from Winnipeg to the Rockies and return. The traverse was continued from Winnipeg east to Ottawa via the Canadian highway.

One project has been proposed at this time involving a fundamental investigation into methods of electrical and electromagnetic geophysical surveying. It was decided to undertake this project because no other government agencies were investigating this subject. However, the lack of suitable scientists has not permitted any actual work along these lines.

An ambitious and diversified seismic program has been outlined consisting of seven projects which are listed as follows:

Project S 1: Fundamental study of microseisms and rock bursts

Project S 2: Study at College Park, Md., of the correlation of microseism production and rock bursts

Project S 3: Preliminary study of shaking tables

Project S 4: Measurement of the dynamic constants of soil

Project S 5: The establishment of new seismic observatories in Northern Canada

Project S 6: N.R.C. investigations of acoustic echo-ranging

Project S 7: A seismic study of the crust of the earth using rock bursts as a source

The N.R.C. has provided a grant of $12,000 toward equipment and expenses and the Dominion Observatory is requesting a similar sum for instruments to be used on Project S 7. A $1,500 grant by the N.R.C. was made for Project S 2 and several specimens of rocks from certain mines affected by rock bursts have been obtained and sent to College Park, Maryland, for preparation.

Other projects involving tectonophysics and electrical phenomena of the earth have been proposed and are in various stages of completion. These projects are listed as follows:

Project T 1: The compilation of geological maps in a series uniform with the 8 mile topographic series

Project T 2: Lineaments of the Precambrian Shield

Project P 1: Spectroscopic and photometric studies of the Aurora

Project P 2: The establishment of additional stations in Northern Canada at which the various aspects of terrestrial electricity can be studied

Project P 3: Observations of the Aurora on Exercise Musk-ox

Project P 4: Measurement of the separation of electric charges arising from the impact of crystals of ice and snow

Project P 5: The establishment of a mobile magnetic observatory to supplement permanent magnetic and ionospheric observatories

It is very gratifying to read this first progress report of the Associate Committee on Geophysics of the N.R.C. of Canada and to realize the degree to which cooperative scientific enterprises can be conducted to mutual advantage by various governmental, industrial and academic organizations. This committee and the N.R.C. of Canada are to be commended for their vision and resourcefulness while acting as the catalyst for promoting and integrating the work of these various organizations in such diversified geophysical fields of research.

R. A. GEYER

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XXVIII. *Les Tremblements de Terre et la Gravitation*, by Cornelio L. Sagui, 1946.

G.–1945. *Cronica Bibliografica (Mineralogia y Mineria, Petrografia, Geologia, Geografia, Paleontologia)*, by Alfredo Castellanos and Pierina Pasotti, 1946.

Report of Proceedings of the Fourth General Assembly of the International Council of Scientific Unions, held at London July 22-24, 1946, edited by F. J. M. Stratton, General Secretary; Cambridge, printed at the University Press 1946, 127 pages. In addition to the report of the meetings of the General Assembly, the book contains reports (partly in French) on recent activities of the following International Scientific Unions: Astronomical, Geodesy and Geophysics, Chemistry, Radio, Pure and Applied Physics, Geography, Biological Sciences. A number of appendices are included giving reports of various special committees, financial reports, union officers, delegates, etc.

CONTRIBUTORS

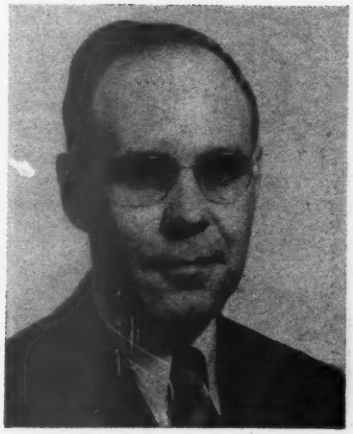
GLENN E. BADER

GLENN E. BADER received the degree of A.B. in Geology in 1927 from Stanford University. Immediately following graduation he accepted the position of geologist for the Cananea Consolidated Copper Company at Cananea, Sonora, Mexico. Since September 1929 he has been employed by the Humble Oil and Refining Company in the Geophysics Department. He served as torsion balance observer, engineer and as computer on a reflection seismograph crew between 1929 and 1933. Since 1933 he has been Chief Computer in the Houston Office. He is a member of the American Association of Petroleum Geologists and of the Society of Exploration Geophysicists.

W. BAXTER BOYD received the degree of B.S. in Geology at the University of Oklahoma in 1928. Upon graduation he joined the geological staff of W. H. Atkinson at Oklahoma City. In 1933 he was employed by the Continental Oil Company at Ponca City, and since 1935 has been Continental's Oklahoma geologist. He is a member of the American Association of Petroleum Geologists, and is affiliated with both the Tulsa and Oklahoma City Geological Societies.

W. BAXTER BOYD

E. L. ERICKSON received the degree of B.Sc. in C.E. from the University of Alberta in 1935. In 1937 he was employed by the Geophysical Department of Continental Oil Company and served in various capacities on gravity meter and seismograph field parties until 1944. Since then he has been attached to the geological division of the Los Angeles Region of the Company as geophysicist engaged in supervision of California geophysical operations and the interpretation of data. He is a member of the American Association of Petroleum Geologists and of the Society of Exploration Geophysicists.



E. L. ERICKSON

LOUIS W. GARDNER

LOUIS W. GARDNER received his B.S. degree from the Alabama Polytechnic Institute in 1923 and his M.A. degree in Physics from the University of California in 1928, at which time he had passed examinations for a Ph.D. degree. From 1928 to 1930, he was Instructor in Physics at North Carolina State College. Since 1930, he has been seismograph interpreter and seismograph interpretation supervisor with the Gulf Research & Development Company. In these capacities, he has been active in improving interpretation techniques, and in applying them to seismograph data obtained in many of the active prospecting regions. He is a member of the American Physical Society, A.A.P.G., American Geophysical Union, and of Society of Exploration Geophysicists.

ROSS GUNN was born at Cleveland, Ohio, May 12, 1897. As an undergraduate he studied at Oberlin College and at the University of Michigan, graduating from the

ROSS GUNN

latter in Electrical Engineering. In 1920, he became an instructor in physics at the University of Michigan; taught two years and received an M. S. in physics in 1921. During 1922–1923, he was Radio Research Engineer for the U. S. Air Service at McCook Field where he did pioneer work on radio aids to the navigation of aircraft and radio control problems. From 1923–1927 he served as instructor in physics at Yale University where he was in charge of the high frequency laboratory during 1926–1927. Yale University granted him a Ph.D. in 1926. Late in 1927 he joined the Naval Research Laboratory where he was assigned duties of successively greater responsibility in various Divisions. During the war, as Chief Physicist, he was responsible simultaneously for the following jobs: Superintendent, Mechanics and Electricity Division; Superintendent, Aircraft Electrical Division; Technical Adviser to the Laboratory Naval Administration and Senior Technical Director of the Army-Navy Precipitation Static Project. In 1946, he was made Superintendent of a newly established Physics Division. He was cited by the Secretary of Navy 4 September 1945—"For ceptionally distinguished service to the United States Navy in the field of scientific research and in particular by reason of his outstanding contribution to the development of the atomic bomb." Dr. Gunn has recently accepted a job as Director of Physical Research for the U. S. Weather Bureau to carry forward a systematic investigation of the physical processes involved in precipitation and related geophysical problems. He is the author of more than 60 scientific publications and more than 30 issued U. S. patents.

W. E. HOLLINGSWORTH received the degree of B.S. in E.E. from the University of Texas in 1925. In 1925–1926 he was in the Test Course of the General Electric Co. in Lynn, Mass. and Schenectady, N.Y. From 1926 to 1929, he was with the Engineering Department of the Dallas Power and Light Co., Dallas, Texas. From 1929 to 1933, he was Professor of Drawing and Electrical Trades at North Texas Agricultural College at Arlington, Texas. He began geophysical work in 1933 as observer on a seismograph crew for the Sun Oil Co., and has been successively party chief, research computor and party supervisor, which is the position now held, with headquarters in Beaumont, Texas.

W. E. HOLLINGSWORTH

D. Raoul Vajk studied mechanical engineering from 1919 to 1923 at the University of Polytechnics, Budapest, and obtained his Ph.D. degree at the University of Science, Budapest. From 1928 to 1931, Dr. Vajk was engaged by the Torsion Balance Exploration Co., Houston, Texas, as geophysical interpreter. From 1933 to 1946, he was head geophysicist of the Hungarian-American Oil Industrial Co. (Maort) Budapest, a Standard Oil Co. (N.J.) subsidiary. In 1939 Dr. Vajk became an associate professor of Applied Geophysics at the University of Science, Budapest. He published several articles on geophysical problems in various technical periodicals. In October 1946, he immigrated to the United States and has been employed since November 1, 1946, by the Standard Oil Co. (N.J.) working in the Company's New York Office, where he is engaged in geophysical interpretations and research work.

D. Raoul Vajk

Paul R. Warren

Paul R. Warren attended Austin College at Sherman, Texas, for two years, studying Physics and Mathematics. He entered Oklahoma A & M in 1928, receiving a B.S. in Electrical Engineering in 1931, returning a year later for an M.S. in Electrical Theory and Mathematics. He was employed by Continental's Geophysical Department in 1933 as Assistant Operator on a seismograph crew. During the next three years he held the positions of Development Engineer, Operator, and Computer, working mostly in South Texas and California. In 1936 he was made Party Chief in Louisiana and Mississippi an in 1946 became Supervisor for the same area.

Photographs and biographies of contributors to this issue not appearing above have been published previously, as follows: B. G. Swan, Vol. VII, No. 4, p. 425 (October 1942); John Sloat, Vol. IX, No. 4, p. 572 (October 1944); Paul F. Hawley, Vol. VIII, No. 4, p. 435 (October 1943).

THE SOCIETY ROUND TABLE

SOCIETY COMMITTEES

COMMITTEE FOR THE ANNUAL MEETING

GENERAL CHAIRMAN: Cecil H. Green

LOS ANGELES ARRANGEMENTS COMMITTEE

Henry Salvatori, Chairman
Curtis H. Johnson, Vice-Chairman
C. Hewitt Dix
T. P. Ellsworth

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Charles H. Dresbach
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Tulsa

R. Clare Coffin, Chairman
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B. H. Treybig, Jr.

Shreveport

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Mississippi

Ewin D. Gaby, Chairman

Rocky Mountain

Michael J. Walczak, Chairman — Walter Hohag

Harry L. Thomsen

Eastern States

Sigmund I. Hammer, Chairman — Milton B. Dobrin

Maurice Ewing

SPECIAL COMMITTEES

Student Membership

Ralph S. Jackson, Chairman — John H. Hodgson
Dave P. Carlton — Paul L. Lyons
Milton B. Dobrin — James C. Menefee

Best Paper Award

Roland F. Beers, Chairman — M. King Hubbert
W. T. Born — Frederick E. Romberg
Frank Goldstone — Paul Weaver

Geophysical Education

James B. Macelwane, S. J., Chairman — Beno Gutenberg
Perry Byerly — C. A. Heiland
Maurice Ewing — M. King Hubbert

D. C. Skeels

ANNOUNCEMENT OF REGIONAL MEETINGS

Two midcontinent regional meetings are scheduled to follow the Joint Annual Meeting. The first will be held in Houston, Texas on Saturday, April 19, under the direction of W. J. Osterhoudt.

The Tulsa meeting is sponsored by the Geophysical Society of Tulsa and is scheduled for Thursday, May 22, in the Mayo Hotel. R. Clare Coffin, President of the Tulsa Society, is in charge of the program arrangements.

The Eastern Regional Meeting will be in the form of a one-day session to be held in the Auditorium of the Mellon Institute in Pittsburgh, Pennsylvania on Friday, June 6. Headquarters will be conveniently located at the Webster Hall Hotel. Under the direction of Sigmund I. Hammer, plans are being made for morning, afternoon and evening sessions, with a dinner to precede the evening program. Information about the program and reservation forms will be mailed to all S.E.G. members in the Eastern States.

ANNOUNCEMENT OF DEADLINE FOR CASE HISTORIES

The deadline for receipt of additional papers for the Case History Volume has been moved up to July 1, 1947, Henry C. Cortes, Chairman of the Committee on Case Histories, has announced. A few more papers are needed to complete the volume which will probably be published in the fall of this year. Those interested in submitting papers are asked to contact Mr. Cortes, Box 900, Dallas, Texas.

ORGANIZATION OF FIRST LOCAL SECTION

Standing left to right: Stanley W. Wilcox, V. L. Jones, R. Clare Coffin.
Seated, left to right: Colin C. Campbell, E. Jack Handley.

Geophysicists in the Tulsa area, led by R. Clare Coffin and E. Jack Handley, have formed the first local geophysical society to petition for affiliation as a local section under the revised constitution of the Society of Exploration Geophysicists. The Geophysical Society of Tulsa was organized February 4, 1947 at a meeting attended by 60 local members of S.E.G. and guests. Temporary officers elected were R. Clare Coffin, President; E. Jack Handley, Vice-President; and Colin C. Campbell, Secretary.

The first regular monthly meeting, planned informally around a dinner and social hour followed by a business and technical session, was held March 13th in the Student Union of The University of Tulsa. Keen interest in the organization was shown by the attendance of 117 geophysicists and geophysics students, many of whom journeyed from Bartlesville and Ponca City and from the field. The Constitution and By-laws, drafted by V. L. Jones, Stanley W. Wilcox and the temporary officers, were adopted by the membership. Charter members were signed, bringing the total membership to approximately 150. The temporary officers are to serve until the May meeting, at which time permanent officers will be elected from a slate prepared by R. W. Gemmer, John Ferguson and G. N. Smith.

"How Not to Find an Oil Field" was the topic of a round table discussion led by A. J. Barthelmes, John Ferguson, R. A. Weingartner, Karl Dyk, Earl M. Wolters, H. M. Thralls, C. D. Hier and R. B. Hollingsworth. The members of this group presented case histories for the purpose of illustrating errors and discussing possible methods of avoiding their repetition. As an added feature of the meeting, J. E. Hawkins, recently returned from England, gave a brief bulletin on the development of the Decca Navigator System.

It is hoped that the success of this meeting, the first held by a formally organized local group of geophysicists, will provide an incentive for the organization of similar groups in other cities.

PERSONAL ITEMS

(Members are requested to forward material for inclusion in PERSONAL ITEMS to C. C. Campbell, P. O. Box 1614, Tulsa, Oklahoma)

H. V. W. DONOHOO, formerly instructor of geophysics and graduate student at the Colorado School of Mines, is now associated with Professor Ewing of the Columbia University Geology Department in a research project, and also working toward an advanced degree in the graduate school.

R. H. BURTON, associated with Amerada Petroleum Corporation for 17 years, has resigned to enter Southwest Butane Company as a Senior Partner.

ERNEST JACK HANDLEY, formerly Chief Geophysicist for Continental Geophysical Service, was elected Vice-President in charge of seismograph operations for Century Geophysical Corporation, August 1, 1946, upon the formation of that company.

FRANK ITTNER, Chief Seismologist, Pacific Division of Superior Oil Co., has recently moved from 2812 Lake Street, Bakersfield, California to 1205 N. Michigan, Pasadena, California.

J. R. REEVES is now directing the seismograph activities for the Lee Geophysical Exploration and Research Corporation of Cisco, Texas.

WALTER C. BONEBRAKE, seismic party chief for The Atlantic Refining Company, is temporarily located in the Miller Bldg., Minden, Louisiana. His permanent mailing address is P. O. Box 2819, Dallas, Texas.

H. M. EVJEN advises that he could stand the subtropical climate no longer and has moved to the mountains. His new address is P. O. Box 453, Ruidoso, New Mexico.

G. A. FOSTER has resigned from his position with C. H. Frost Gravimetric Surveys, Inc., and has entered private practice as a consultant in gravity interpretation and geological work. His address is 2531 East Third, Tulsa 4, Oklahoma.

MARION H. GILMORE, research geophysicist for the U.S. Navy, is now working on the problems found in using microseisms to detect, track, and locate hurricanes and typhoons. The navy now has ten microseismic stations in the Caribbean and the Pacific and the method has already demonstrated its practical value in forecasting severe tropical storms.

ALFRED J. HIBBLER has resigned from the Texas Co. after 26 years service to enter private practice. His address is now 4414 Woodside Drive, Houston 3, Texas.

G. R. JOHNSON has organized a firm known as "Radar Exploration Company" for the purpose of developing, installing, and leasing modified radar equipment for surveying use in off-shore work. His address is now Box 308, Toronto, Ontario, Canada.

GERALD H. WESTBY, President of Seismograph Service Corporation, was recently elected president of the Tulsa Chamber of Commerce.

LT. COL. GEORGE B. KAISER is now temporarily stationed in Winter Park, Florida. During 1946, Col. Kaiser was relieved from duty at Headquarters Army Air Forces in

Washington, D. C. and transferred to Mitchell Field, Long Island where he was in charge of the Electronics Branch of the Assistant Chief of Staff, A-6 Division. Later he was transferred to Orlando, Florida where he was assigned as Assistant Chief of Air Staff, A-6, of the 14th Air Force.

HUGH MCCAIN JR., formerly associated with the Atlantic Refining Co. as a senior computer, has accepted a new position as interpreter with the Nance Exploration Co. of Houston, Texas. Mr. McCain may be addressed at P. O. Box 774, Hattiesburg, Miss.

H. W. STRALEY, III, consulting geological and geophysical engineer, of Washington, D. C. and Princeton, W. Va., has joined the staff of the International Bank and will have charge of valuation of mining and oil properties. His new address is Box 5532, Friendship Station, 16, D. C.

R. B. MORAN, JR., recently returned from the atom bomb tests at Bikini, is now stationed at the U.S. Naval Research Lab. at Pasadena, California as an electronic engineer.

DELBERT F. SMITH resigned his position as geologist for The Atlantic Refining Company some time ago, and has since been associated with the Oklahoma Geophysical Company as a partner.

EDWARD J. WALTER, until recently with Shell Oil Co., Inc. of Houston, is now assistant director of seismological observation and associate professor of mathematics at John Carroll University, University Heights, Cleveland 18, Ohio.

W. M. WHITLEY resigned his position as interpreter for Gulf Research & Development Co. in October, 1946, to become party chief for the Nance Exploration Co. of Houston, Texas. His present mailing address is P. O. Box 774, Hattiesburg, Miss.

THEODORE KOULOMZINE, senior partner of Koulomzine, Geoffroy, Mossard & Co., was elected chairman of the Committee on Geophysics, Instruments and Equipment of the Geology Division of the Canadian Institute of Mining and Metallurgy, in March, 1946. This committee was the first organization grouping men actively engaged in geophysical prospecting in Canada. Two meetings were held and important matters, both legal and technical were discussed. As a result of this work, for the first time in its history, the C.I.M.M. is devoting an entire session of its technical program at this year's Annual Meeting at Ottawa to geophysical prospecting.

ROLAND F. BEERS, president of The Geotechnical Corporation, is currently serving as Chairman of the Committee on Geophysical Sciences of the Joint (Army & Navy) Research and Development Board, Washington, 25, D. C.

DR. C. A. HEILAND of the Heiland Research Corporation and Geophysical Exploration Company has been elected President of the Rocky Mountain Association of Geologists. The other new officers of the Association are: Robert McMillan, 1st Vice-President; A. W. Cullen, 2nd Vice-President; and N. W. Bass, Secretary-Treasurer. The Association recently changed its name from "Rocky Mountain Association of Petroleum Geologists" to "Rocky Mountain Association of Geologists."

MR. KENNETH E. BURG, former head of the Geophysical Department, Stanolind Oil & Gas Co., Tulsa, Oklahoma, has resigned to accept the position of Consulting

Geophysicist with Geophysical Service, Inc. Mr. Burg is a graduate of the University of Texas where he majored in Physics and Mathematics and received the degree of Electrical Engineering. He has been doing geophysical work since 1927, having been previously associated with Geophysical Research Corporation and Geophysical Service, Inc., before joining Stanolind in 1942.

LT. ROBERT C. HANNUM, recently returned from service in Japan with the 69th Engr. Topo. Battalion, is now assigned to the Aviation Engineering Training Center at Geiger Field, Washington as Information-Education Officer.

JOHN CARR, after a short visit in the United States, is returning to England en route to Cairo, Egypt to resume his work with the Shell Oil Co. of Egypt.

The following extracts from a recent letter from Professor Mintrop are published as they will probably give the first news which most of our members will have of one of the honorary members of the Society. (Ed.)

22a Essen-Werden
Barkhovenalle 36
December 31, 1946

Dear Mr. Eby,

Your kind letter, October 25, . . . has been duly received. . . . My wife, my daughter and I are so happy to have heard of you, Mrs. Eby, your daughters and "all of my Friends in Houston." During the past eight years since I had been for the last time in the sunny south I never forgot my friends and so did my family and we are happy that you and they remember us. We send the very best greetings to all of them, especially to you and your family as well as to Mr. Walter Walne, Brady Cole, Clarence Wharton, Palmer Hutcheson, Mr. Shepherd of the firm Baker, Botts, Andrews and Wharton, including their families. Furthermore to Mr. W. F. Henniger, L. P. Garret, Paul Weaver Alexander Wolf, of the Gulf, Mr. Harry Hanszen, Mr. Hassellast not least Mr. A. T. Schwennesen and his family. I hope that they are all in good health. . . . I am just a professor now, I have written several papers in the course of the last years on the principles and use of geophysical methods of Exploration, copies of which I shall send to you as soon as it will be possible. . . . In the meanwhile the artificial earthquakes by blastings had their centenarian in 1946 and the physical earthquake-investigations shall have it in 1947. In memory of this interesting data I have prepared a paper dealing with the relations between physical Seismology and the study of artificial earthquakes. I am wondering where I can publish this paper some day. Hoping that I can see the sunny south again, I remain with the best regards and good wishes for the new year, sincerely yours,

L. Mintrop

JAMES D. BERWICK resigned as consulting geophysicist for Imperial Oil Ltd., Toronto, Canada to become associated with the Rocky Mountain Land and Leasing Corp. (as Secretary-Treasurer), the Reynolds Gas Service and Appliance Co., and Voltz Drilling Co., and may be addressed at P. O. Box 1478, Pueblo, Colorado.

G. D. KENDALL, with Amerada in the Geophysical Department for 17 years, has accepted a new position as geophysical supervisor for Deep Rock Oil Corporation.

JOHN A. LESTER, recently moved from the Houston District to the Dallas home

office of Magnolia Petroleum Co., is still supervising the Gulf Coast Area. His address is now Box 900, Dallas, Texas.

MRS. FRANCIS E. SMITH who recently accepted a new position as office computer with Kerr-McGee Oil Ind. Inc. after working three years for Continental Oil Company on a seismograph crew, made the transfer to be with her husband who is in Medical School in Oklahoma City.

J. P. GARNER, with the Texas Company for 11 years in the Geophysical Division, became Manager of Oil Exploration Co., Inc., 604 McBirney Bldg., Tulsa, Oklahoma this past year.

JOHN P. HAMMETT, newly elected student member of the Society, served in the Air Corps three years, half of which time he was a weather equipment technician attached to the Signal Corps Engineering Laboratories in New Jersey. He has now returned to the University of Tulsa as a senior in engineering, to complete his work under the G. I. Bill.

JOHN MUELLER LOHSE, formerly a development engineer for the Naval Ordnance Laboratory working with underwater ordnance devices, is now a research engineer with Consolidated-Vultee Aircraft Corporation. His address is 128 Jewel St., Longview, Texas.

PHIL F. MARTYN has opened an office as consultant in petroleum geology, at 2703 Gulf Bldg., Houston 2, Texas.

C. J. COURTNEY has obtained leave of absence from his position with the California Company to do post graduate work at the University of Colorado.

PAUL D. CRAWFORD, SR., consulting geophysicists with offices at 1421 Milam Building, San Antonio 5, Texas, is working in the Abilene District

M. O. GIBSON, administrative assistant with Shell Oil Co., has been transferred to Midland, Texas as assistant to the Exploration Manager of the newly organized Midland Area. His address is now Box 1509, Midland, Texas.

PAUL GREENLEE returned to Petty Geophysical Engineering Co. as a seismologist after serving 41 months with the U.S. Navy as a Radar Officer.

JAMES E. KAMITCHIS, graduate assistant at the University of Oklahoma, is working toward a Master's Degree in Physics.

HOWARD MCMURRAY resigned as seismologist with Shell Oil Company to assume position as investigator with the New Jersey Zinc Co. He may be addressed in care of the Technical Department, Palmerton, Pa.

HERBERT H. MOODY, formerly with Continental Oil Company as a development engineer, has joined with M. C. Kelsey, E. F. McMullin and E. E. Nolen to organize the Rayflex Exploration Company with headquarters at 6923 Snider Plaza, Dallas 5, Texas.

COL. CHAS. GILL MORGAN is now engaged in special research at Howard University. His address is still 287 Waltham St., W. Newton 65, Mass.

JAMES H. TODD, geologist with The California Company, has transferred from the Geophysical Department to become development geologist for the Brookhaven and Mallalieu Felds, Lincoln County, Mississippi, and is stationed at 125 North Jackson, Brookhaven, Miss.

CHARLES A. DURHAM has recently become re-associated with Humble Oil & Refining Co. as a geologist, and has been assigned to the West Texas Division, with headquarters at Box 1600, Midland, Texas.

HENRY FAUL has taken up new work as a research associate in the Laboratory of Nuclear Science and Engineering of Massachusetts Institute of Technology, working primarily on radiation measuring instruments. Last summer he served four months as scientific technician with the Radiological Safety Section, Joint Task Force 1, for the Atomic Bomb Tests at Bikini.

W. OBIER MARTIN is now on an educational leave of absence from the Texas Petroleum Company to study petroleum engineering at Louisiana State University. He may be addressed at Box 5441, University Station, Baton Rouge, Louisiana.

A. E. BERNDES, JR., party chief for The Texas Company, is now working at Alva, Oklahoma.

After returning from Bikini, where he served as civilian scientist making earth wave measurements for the Navy, Carson L. Doss left The Geotechnical Corporation to take charge of the instrument shop of the Colorado School of Mines.

EDGAR A. FAIN has accepted a position as Industrial Methods Engineer, acting head of the Industrial Methods Section of the National Housing Agency, Washington, D. C. His new address is Apt. 201, 913 N. Wayne St., Arlington, Va.

HOMER JENSEN, formerly a physicist in the Naval Ordnance Laboratory, Washington, D. C., is now in charge of all airborne magnetometer work for Aero Service Corporation.

W. HARLAN TAYLOR, until recently with Petty Geophysical Engineering Co., has organized the Taylor Exploration Company of which he is president, and is doing consulting and contracting geophysical work.

KIRBY J. WARREN has left the Carter Oil Company and is now with Sinclair Prairie Oil Co. as a computer. He is presently located in Ft. Worth, Texas at 901 Fair Bldg.

NOEL FROST, Assistant Instrument Supervisor for Seismograph Service Corp., is currently located at the Institute du Petrole, 2 Rue de Lubeck, Paris 16, France, as an instructor in the American technique of seismic exploration.

WILLIAM THOMAS HOLSER, lecturer in Geology at Columbia University, will be associated during the Spring Term with Dr. Sidney Paige in presenting a new course in Engineering Geology. Dr. Paige is a visiting Professor this year at Columbia.

RAYMOND L. SARGENT, formerly a seismograph party chief for Apache Exploration Co., has opened a new firm, Raymond L. Sargent, Magnetometer Surveys. Mr. Sargent may be addressed at 623 M. & M. Building, Houston 2, Texas.

ROBERT F. VAN CLEAVE, with National Geophysical Company for nine years as a party chief and supervisor, has resigned to accept the position of district seismic supervisor, South Louisiana district, with The Atlantic Refining Company, headquarters Lake Charles, Louisiana.

L. DON LEET, Director of the Harvard Seismograph Station at Harvard University, is currently acting as special consultant to the Panama Canal for the Isthmian Canal Studies aimed at selecting a route and type of canal for recommendation to Congress.

J. GORDON COLE is now in Nassau, Bahamas, B. W. I., as geologist and technical advisor for Nassau Oil Mining Company, Ltd. His address is P. O. Box 1093, Nassau, Bahamas.

LYNN D. ERVIN, after his release from active service with the U. S. Marine Corps, resumed work with his former employer, Stanolind Oil and Gas Co., as a seismograph party chief.

E. B. LINDSEY, party chief for Seismograph Service Corp., is in France on a six months assignment to instruct crews operated by the Compagnie Generale de Geophysique in present methods of seismic exploration. This course in operation procedure is provided by the French Government.

COL. JOHN V. LONG has returned to civilian life after 5 years and 9 months with the army. He is again with Solar Aircraft Company as a research physicist.

ROBERT L. MIMS has obtained leave of absence from Shell Oil Co., Inc. to complete work on an M. A. Degree in Physics with a minor in Geology at the University of Texas. Upon completion of this work, he expects to return to the Shell Geophysical Department, with which he has been associated for over 10 years.

JAMES K. RILEY, Jr., stationed in the Dominican Republic for the last year and a half as an observor for the Independent Exploration Company, has been transferred to Cuba.

G. A. SCHOFIELD, party chief for The Texas Company, is now assigned to the Rocky Mountain Division, working in Utah and Wyoming. He may be addressed in care of L. A. Scholl, Jr., Houston 1, Texas.

F. F. CALHOUN, formerly with Stanolind Oil & Gas Co., is now a party chief for the Garrett Exploration Company, located at present in Covington, La.

V. G. FEATHER resigned his position with Kerr-McGee Oil Industries, Inc. to become a geologist-seismologist with Honolulu Oil Corporation last July.

ROBERT L. CRAIG, Research Engineer for the Carter Oil Company, has recently returned to the United States after a two-year assignment in Cuba. He may be addressed in care of the Carter Oil Company, Box 801, Tulsa, Oklahoma.

J. R. BRADLEY, JR. has been promoted to party chief for Stanolind Oil and Gas Co., and transferred from Casper, Wyoming to Vernon, Texas.

JAMES G. JACKSON, JR. returned in October from more than two years duty with the Army Airways Communication System as a Cryptographic Technician, in both Greenland and Iceland. He is now Chief Computer for Western Geophysical Co.

SIGMUND HAMMER recently was appointed to the faculty of the University of Pittsburgh as lecturer in Geophysics. He will teach a course in Geophysical Prospecting to students majoring in petroleum and geological engineering. The university appointment is in addition to his work at the Gulf Research & Development Co.

MARTIN C. KELSEY, formerly with Geophysical Service Inc. as a Supervisor, is now with the Rayflex Exploration Co. with offices at 6923 Snider Plaza, Dallas 5, Texas.

A. J. ODEN, seismic party chief for Magnolia Petroleum Company, is working out of Sulphur, Oklahoma at present.

DAVID H. SCOTT, Geologist with The Texas Co., has returned to his office in Bakersfield, California after completing seismic interpretational work in Oregon and Washington.

K. L. KIPFER resigned as gravity meter party chief for Continental Oil Company and is now employed by Black and Veatch, Consulting Engineers, Kansas City, Mo., as a civil engineering designer.

KARL H. SCHMIDT is now sole owner of Petroleum Service Company, San Antonio, Texas, engaging in petroleum reservoir engineering.

S. P. WEATHERBY resigned his position with Keystone Exploration Company to direct geophysical activities for Southern Minerals Corp., 411 North Broadway, Corpus Christi, Texas.

WILLIS H. FENWICK, in partnership with Richard C. Klett and Carey B. Schmid, has formed the Intermountain Exploration and Engineering Co. to do gravity meter exploration, consulting geology and geophysics ,and well elevation service in the Rocky Mountain Region.

E. F. MCMULLIN, formerly Party Chief with Geophysical Service Inc., has joined the Rayflex Exploration Company, 6923 Snider Plaza, Dallas, Texas.

WILLIAM E. WALLIS now holds the position of General Manager with the International Ecuadorean Petroleum Co., Guayaquil, Ecuador, replacing B. F. Zurich who was transferred to Peru.

FREDERICK W. BROWN, field operator for Geo-Technical Development Co., Ltd., is working at present in the nickel-copper country of Northern Manitoba.

ROBERT H. MANSFIELD, finishing his second year in Venezuela, is now Senior Seismologist for Venezuela, Colombia and Trinidad for the United Geophysical Company, S. A., and is located at Caracas.

MALCOLM S. MORRISON has returned from Venezuela, and is now associated with C. C. Smith Drilling Co., in Lubbock, Texas.

WILLIAM R. PERRET has returned to the Waterways Experiment Station as Chief of Physical Measurements Section, charged with all geophysical field work and instrument development for the Soils Division of the Station.

EDWARD I. GRIZZELL, party chief with Independent Exploration Co., was transferred recently from Bahrein Island, Persian Gulf to Haifa, Palestine.

SOCIETY OF EXPLORATION GEOPHYSICISTS
MEMBERSHIP LIST (APRIL, 1947)

Acheson, C. Harold (Party Chief Gravity Meter & Magnetometer), c/o International Ecuadorian Pet. Co., Guayaquil, Ecuador, S. A.
Acheson, Volney A. (Research Geophysical Engineer), c/o Creole Petroleum Corp., Apartado 889, Caracas, Venezuela, S. A.
Adams, Hal Robert (Party Chief, Geotechnical Corp.), Box 7166, Dallas, Tex.
Adams, John Army (Party Chief), c/o Western Geophysical Co., 306 W. 2nd St., Roswell, N. M.
*Adams, Myron D. (Observer, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
*Adams, Robert W. (Engineer and Member of Firm, Adams & Associates), 7400 Tampa Ave., P. O. Box 664, Reseda, Calif.
Aderman, C. V. (Party Chief, Keystone Exploration Co.), 2813 Westheimer Rd., Houston, Tex.
Adler, Joseph L. (Foreign Manager, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Affleck, James (Geophysicist-Magnetics, Gulf Research & Development Co.), P. O. Drawer 2038, Pittsburgh 30, Pa.
Agee, Flint Humphrey (Seismograph Party Chief, United Geophysical Co.), 6115 Middleton St., Huntington Park, Calif.
Agnich, Fred Joseph (Party Chief, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Agocs, William B. (Assistant Professor of Physics, Lehigh University), 940 Broadway, Bethlehem, Pa.
Aiken, Charles B. (Vice-President and Director of Research, Electro-Mechanical Research, Inc.), Wilborn, Conn.
Alber, John L. (Head of Geophysics Dept.), International Petroleum Co., Negritos, via Talara, Peru, S. A.
*Albertson, Dorothy Earle (Assistant Computer, The Texas Company), 823 S. Palace Ave., Tyler, Tex.
Albright, Emory Glenn (Party Chief, Atlantic Refining Co.), 1511 19th Ave. So., St. Petersburg, Fla.
Alcock, E. D. (Supervisor, National Geophysical Co.), 3412 Caruth Blvd., Dallas 5, Tex.
Aldredge, R. F. (Geophysicist), Westby Geophysical Corporation, c/o Petroleos Mexicanos, Departmento Exploracion, Tampico, Tamps, Mex.
Allen, Lynn D. (Seismic Computer), c/o Socony-Vacuum Oil Co. C. A., Apartado 246, Caracas, Venezuela, S. A.
Allen, Thomas L. (District Supervisor, Petty Geophysical Engineering Co.), P. O. Drawer 2061, San Antonio, Tex.
†Allen, William, Jr. (Student, Colorado School of Mines), Beta Theta Pi House, Golden, Colo.
*Allen, William E. (Assistant Superintendent, Geoph. Section, Cities Service Oil Co.), 1009 Osage, Bartlesville, Okla.
Allon, Michael (Geophysicist, Gulf Research & Development Co.), 1033 Farragut St., Pittsburgh 30, Pa.
Alverez, Manuel, Jr. (Geologist of Central Exploration Dept., Petroleos Mexicanos), Pub: Nogal 52, Mexico City, D. F.
Anderson, John F. (Chief Geophysicist, Geophysical Engineering Co.), 411 Beacon Bldg., Tulsa, Okla.
Anderson, O. W. (Seismograph Interpreter, Stanolind Oil & Gas Co.), 2344 McClendon Rd., Houston 5, Tex.
Andrews, Harry H. (Supervisor, Seismograph Service Corp.), 709 Kennedy Bldg., Tulsa, Okla.
Arick, M. B. (Independent Geologist), 211 North A St., Midland, Tex.
*Armstrong, John A., Imperial Oil Limited, Exploration Dept., 606 2nd St. West, Calgary, Alberta, Canada.

* Associate Member † Student Member ‡ Honorary Member

Armstrong, Lee C. (Geologist, E. J. Longyear Co.), 1701 Foshay Tower, Minneapolis 2, Minn.
Arnett, R. D. (Partner, Seismic Engineering Co.), 6622 Robin Road, Dallas 5, Tex.
Arnold, Kingsland (Gravity Computer, Magnolia Petroleum Co.), P. O. Box 900, Dallas 1, Tex.
Arthur, Marion A. (Research Geophysicist, Humble Oil & Refining Co.), 29 Humble Bldg., Houston 1, Tex.
Athy, L. F. (Chief Geophysicist), c/o Continental Oil Co., Ponca City, Okla.
Atwater, Gordon I. (Chief Geologist, Wm. Helis), 912 Whitney Bldg., New Orleans, La.
Augenthaler, Robert L. (Geologist, Standard Oil Co. of Calif.), Geophysical Office, P. O. Box 1200, Bakersfield, Calif.
Augustat, George (Party Chief, Seis., Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Augusteijn, J. J. (Seismologist), c/o Shell Co. of Ecuador, Quito, Ecuador, S. A.
Aurand, Harry A. (Consulting Geologist and Geophysicist), 1350 Bellaire St., Denver 7, Colo.
Autrey, D. W. (Computer, Geotechnical Corp.), P. O. Box 7166, Dallas 9, Tex.
Ayres, Joel Otis (Seismologist, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.

Baars, Bastiaan (Physicist, B. P. M.), Carel van Bylandtlaan 30, The Hague, Netherlands.
Babb, John J. (Party Chief, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Backman, John E. (Party Manager, Gulf Research & Development Co.), P. O. Drawer 2038, Pittsburgh 30, Pa.
Bacon, Lloyal O. (Research Asst. in Geophysical Exploration), School of Mineral Industries, Pennsylvania State College, State College, Pa.
Bader, Glenn E. (Chief Seismic Computer), c/o Humble Oil & Refining Co., 802 Humble Bldg., Houston, Tex.
Bailey, Lothrop H. (Geophysicist, Gulf Research & Development Co.), P. O. Drawer 2038, Pittsburgh 30, Pa.
Baird, John, Franklin Hall, Cornell University, Ithaca, N. Y.
Baird, Walter D. (Party Chief, Geophysical Service, Inc.), 6000 Lemmon Ave., Dallas 9, Tex.
Balbin, Paul D. (Seismograph Supervisor, Stanolind Oil & Gas Co.), Box 1410, Ft. Worth, Tex.
Ballard, James A. (Party Chief, Seismograph Service Corp.), 507 Raton Ave., La Junta, Colo.
Banta, H. E. (Research Physicist, Independent Exploration Co.), Box 6007, Houston 6, Tex.
Banta, Norman H. (Party Chief, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Barber, R. Curtis (Engineer, Schlumberger Well Surveying Corp.), 19, Chestnut St., Bradford, Pa.
Barbisch, Joe B. (Seismologist, Petty Geophysical Co.), Box 2061, San Antonio, Tex.
Barbour, Price C. (Gravity Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Barclay, Steward (Geophysicist, Phillips Venezuelan Oil Co.), Apartado 1031, Caracas, Venezuela, S. A.
*Barkouky, A. N. (Asst. Geophysicist), c/o Anglo-Egyptian Oilfields, Ltd., Shell House, Cairo, Egypt.
Barksdale, Gerald L. (Party Chief, Pietty Geophysical Co.), Casilla 320, Ambato, Ecuador, S. A.
Barnes, Chester F. (Consultant in Geology and Geophysics), Box 266, Big Spring, Tex.
Barnett, L. Atmar M. (Research Geophysicist, Humble Oil & Refining Co.), Rt. 17, Box 1745, Houston, Tex.
Barret, William M. (President), Wm. M. Barret, Inc., 909 Giddens-Lane Bldg., Shreveport, La.

Barthelmes, Albert J. (Vice-President, Seismograph Service Corp.), 1630 E. 26th Pl., Tulsa 5, Okla.
Batchelder, Dean E. (Electrical Engineer, Lane-Wells Co.), 4037 W. 61st St., Los Angeles 13, Calif.
*Bates, Charles C. (Assoc. Oceanographer, Hydrographic Office, Navy Dept.), 4732 Homer Ave., S.E., Apt. D, Washington 20, D. C.
*Batson, James B. (Geophysics Dept., Magnolia Pet. Co.), Box 900, Dallas, Tex.
Baum, Robert (Party Chief, Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
Bazhaw, W. O. (Gravity Supervisor, Petty Geophysical Co.), 2208 Transit Tower, Unit 5, San Antonio, Tex.
Bazzoni, Charles B. (Chief Geophysicist), c/o Sun Oil Co., Geophysical Lab., Norwood, Pa.
Beck, August F. (Chief Geophysicist), c/o Imperial Oil Co., 56 Church Street, Toronto, Ontario, Canada.
Becker, H. C. (Party Chief), c/o Seismograph Service Corp., Box 1590, Tulsa, Okla.
*Bediz, Pertez I. (Geophysicist), M. T. A. Enstitusu, Ankara, Turkey.
*Beebe, B. W. (Chief Geologist), c/o The Bay Petroleum Corp., Box 957, Denver, Colo.
Beeman, Keith R. (Electrical Engineer), Southwestern Industrial Electronic Co., 5107 Locust, Bellaire, Tex.
Beers, Roland F. (President, Geotechnical Corp.), 3712 Haggar Way, P. O. Box 7166, Dallas 9, Tex.
Beeth, C. Donald (Geologist, Continental Oil Co.), Box 2197, Houston, Tex.
Bemrose, John (Geophysicist), c/o The Caribbean Pet. Co., Geophysical Section, Apartado 809, Caracas, Venezuela, S. A.
†Bender, Fred A. (Dir. of Seismology Dept.), Geophysics Dept., University of Pittsburgh, 428 Cathedral of Learning, Pittsburgh 13, Pa.
Benioff, Hugo (Assoc. Prof. of Seismology, Calif. Inst. of Tech.), 220 N. San Rafael Ave., Pasadena 2, Calif.
Benke, M. L. (Seismologist, Texas Co.), 2111 Wroxton Rd., Houston 5, Tex.
*Bennett, Elwin (Gravity Party Mgr., Petty Geophysical Engineering Co.), Box 2061, San Antonio, Tex.
Bennett, Roy F. (Division Geophysicist, Sohio Pet. Corp.), 6th Floor, Neils Esperson Bldg., Houston 2, Tex.
*Beresford, Robert (Electrical Engineer, Naval Ordnance Lab.), 2009 Branch Ave., S. E., Washington, D. C.
Berg, G. A. (President, Berg Geophysical Co.), 2626 Westheimer, Houston, Tex.
Berndes, A. E., Jr. (Party Chief, Texas Co.), Box 2332, Houston 1, Tex.
Bertolet, Edward C. (Engineer, Superior Oil Co.), Box 2508, Los Angeles 53, Calif.
Bertram, A. C. (Engineer, John O. Harmon), 6403 Edloe, Houston 5, Tex.
Berwick, James D. (Secretary-Treasurer, Rocky Mt. Land & Leasing Corp.), Box 1478, Pueblo, Colo.
Bevan, Thomas J. (Partner, Mayes-Bevan, Inc.), 305 Kennedy Bldg., Tulsa, Okla.
Bevier, George M. (Independent Geologist), Security Bldg., Pasadena, Calif.
Bhattacharya, P. K. (Graduate Student), Calif. Institute of Tech., Pasadena 4, Calif.
Bible, John L. (Executive Vice-President, North American Geophysical Co.), 216 West Cowan Dr., Houston 7, Tex.
Bickel, Harold C. (Chief Geophysicist), c/o Tropical Oil Co., Apartado Aereo 3533, Apartado Nacional 335, Bogota, Colombia, S. A.
Bills, Robert N. (Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
*Birkenhauer, Rev. Harry F., S. J. (Teacher of Physics and Mathematics, John Carroll University), 5629 State Road, Cleveland 9, Ohio.
Bishop, F. L. (Consulting Geophysicist), 604 National Bank of Tulsa Bldg., Tulsa, Okla.
Black, J. P. (Mgr. Geology and Lease Div.), American Republic Corp., 1810 Petroleum Bldg., Houston, Tex.
Blakey, Carl W. (Supervisor, Seismograph Service Corp.), c/o Shell Company, Box 228, Cairo, Egypt.
Blanchard, Charles H. (Party Chief), c/o Arkansas Fuel Oil Co., Geophysical Dept., Shreveport, La.

†Blanchard, Jonathan E. (Student), Geophysics Dept., University of Toronto, Toronto 6, Ontario, Canada.
Blanchard, William G. (Principal Associate, Wm. G. Blanchard & Associates), Box 593, Coral Gables 34, Fla.
Blau, L. W. (Research Consultant), c/o Humble Oil & Refining Co., Box 2180, Houston 1, Tex
*Bloomer, P. A., Jr. (District Geologist, Louisiana Geological Survey), Box 8523 University Station, Baton Rouge 3, La.
Blum, Victor J., S. J. (Asst. Dean, Inst. of Geophysical Technology), 3621 Olive St., St. Louis 8, Mo.
Blundun, George J. (Seis. Party Manager, Gulf Research & Development Co.) Box 600, Red Deer, Alberta, Canada.
Boccalery, Michael A. (Geophysicist, Western Geophysical Co.), 711 Edison Bldg., Los Angeles, Calif.
Bolinger, John W. (Office Computer, Humble Oil & Refining Co.), 808 Humble Bldg., Houston, Tex.
Bondurant, John E. (Chief Observer), Phillips Petroleum Co., Geophysical Lab., 400 W. 3rd St., Bartlesville, Okla.
*Bonebrake, Walter C. (Seismologist), Atlantic Refining Co., Geoph. Sect. Party #15, Box 2819, Dallas, Tex.
Boots, Paul H. (Geophysicist), Colombian Gulf Oil Co., Aptdo. Nacional 1339, Bogota, Colombia, S. A.
Boos, C. Maynard (Geologist, Barnsdall Oil Co.), 2036 S. Columbine St., Denver, Colo.
Borman, Frank W. (Geophysicist, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Born, Milton C. (Party Chief), Amerada Petroleum Corp., 552 Subway Terminal Bldg., Los Angeles 13, Calif.
Born, William T. (Director of Laboratory, Geophysical Research Corp.), 2607 N. Boston Pl., Tulsa, Okla.
Boucher, F. G. (Head of Development Engineering, The Carter Oil Co.), 3611 So. Utica, Tulsa 5, Okla.
Bowler, Gordon E. (Chief Electrical Engineer, Atlantic Refining Co.), 410 East Fifth St., Dallas 8, Tex.
*Bowman, D. C. (Lab. Technician, Seismograph Service Corp.), 2620 E. Archer, Tulsa, Okla.
Bowsky, Merle C. (Asst. Director of Engineering, Hq. Sig. C. Eng. Lab.), 2215 Oakdale, Houston, Tex.
Boyd, Lewis H. (Geophysicist), c/o Brown Geophysical Co., Box 6005, Houston, Tex.
Bradford, Donald C. (Chief Engineer, Serdex Corporation), 50 Follen St., Cambridge 38, Mass.
Bradley, Waring (Geologist, Permian Basin Sample Lab.), Box 1653, Midland, Tex.
Bradley, Joe R., Jr. (Party Chief, Stanolind Oil & Gas Co.), Box 2008, Vernon, Tex.
Bradley, R. M. (Chief Geophysicist, Cities Service Oil Co.), 413 Masonic Bldg., Bartlesville, Okla.
Brant, Arthur A. (Associate Professor, University of Toronto), 515 Jarvis St., Toronto 5, Ontario, Canada.
Braun, Theodor H. (Manager Geophysical Lab., Superior Oil Co.), 1552 Blanche St., Pasadena 4, Calif.
*Brayton, Arnold E. (Seis. Party Chief), Surinaam Bauxite Maatschappij, Box 218, Paramaribo, The Suriname (S. A.).
Breck, Howard R. (Geophysical Supervisor), c/o Seismograph Service Corp. of Dela., Apartado 1488, Caracas, Venezuela, S. A.
*Breedlove, Ruth (Computer), c/o Atlantic Refining Co., Box 2819, Dallas, Tex.
Brenner, Morris (Materials Engineer, National Bureau of Standards), 3855 Rodman St. N. W., Washington 16, D. C.
Briard, Vernon E. (Geophysicist in Charge of Gravity & Magnetic Exploration & Interpretation, Texas Co.), 4202 Swarthmore, Houston, Tex.
Brinnon, W. B. (Seis, Party Chief, Magnolia Petroleum Co.), Box 608, Lovington, New Mex.
Brons, H. H. (Geophysicist), c/o B. P. M., Carel van Bylandtlaan 30, The Hague, Holland.

Brooks, James A., Jr. (Geophysicist, Humble Oil & Refining Co.), 2516 Ella Lee Lane, Houston, Tex.
Brotherhood, G. Roy (Geophysicist), c/o Caracas Pet. S. A., Apartado 89, Caracas, Venezuela, S. A.
Broussard, C. H. (Supervisor, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Broussard, D. F. (Geophysicist, Yegua Corp.), 2302 Esperson Bldg., Houston, Tex.
Brown, Andrew (Laboratory Technician, Atlas Exploration Co.), 1911 West Alabama, Houston 6, Tex.
Brown, Doland R. (Geophysicist), c/o Shell Oil Co., Inc., Houston, Tex.
†Brown, Frederick W. (Field Operator), c/o Geo-Technical Development Co., Ltd., Bourlamaque, P. Q. Canada.
Brown, H. Hallock (Seis. Party Chief, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
Brown, Hart, (Owner, Brown Geophysical Co.), P. O. Box 6005, Houston, Tex.
Brown, Henry W. (Geophysicist, Carter Oil Co.), Box 801, Tulsa, Okla.
Brown, L. I. (District Geologist), c/o California Company, 1818 Canal Bldg., New Orleans 12, La.
Brown, Leon D., Jr., 1904 Rio Grande, Austin, Tex.
Browning, K. A. (District Manager, Illinois Powder Mfg. Co.), 3120 Grand Ave., Dallas, Tex.
Browning, Paul (District Petroleum Engineer), c/o Creole Petroleum Corp.), Apartado 172, Maracaibo, Venezuela, S. A.
Brownlow, C. L. (Supervisor of Geophysical Lab., Phillips Petroleum Co.), Room 104, Research Bldg., Bartlesville, Okla.
Bruyere, R. N. (Party Chief, Texas Co.), Box 2332, Houston, Tex.
Bryan, A. B. (Chief Geophysicist, Carter Oil Co.), 1624 E. 37th St., Tulsa, Okla.
Bryan, Carl L. (Geophysicist), c/o Gulf Refining Co., Drawer 1731, Shreveport, La.
*Buckner, Guy O., Jr. (Lab. Technician, Texas Co.), P. O. Box 425, Bellaire, Tex.
Buckner, Harry M. (Exploration Coordinator, Carter Oil Co.), Drawer 1739, Shreveport, La.
*Budd, Montgomery R. (Asst. Director of Advertising, Hercules Powsder Co.), 718 Greenhill Ave., Wilmington, Dela.
Buffum, C. E. (Technical Group Advisor, Stanolind Oil & Gas Co.), 1527 E. 36th Pl., Tulsa, Okla.
Bugbee, J. M. (Senior Exploitation Engineer, Shell Oil Co., Inc.), 2624 West Lane, Rt. 4, Box 735, Houston, Tex.
Bunsen, A. W. (Asst. Party Chief, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Burg, Kenneth E. (Consulting Geophysicist, Geophysical Service Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
*Burnett, Arthur C. (Part Owner), Langnam, Langston & Burnett, 1300 Prairie Ave., Houston, Tex.
Burroughs, B. B. (Gravity Meter Supervisor), Arkansas Fuel Oil Co., Shreveport, La.
Burton, G. A. (Seismologist), c/o Shell Oil Co., Inc., Box 720, Casper, Wyo.
Burton, R. H. (Partner), Southwest Butane Company, Box 601, Big Lake, Tex.
Butler, Mark D. (Seismic Interpreter), c/o Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Butler, W. W. (Geophysical Supervisor), c/o Tide Water Associated Oil Co., Box 1404, Houston, Tex.
Butt, Harding (Party Chief, Atlantic Refining Co.), Box 2819, c/o Geophysical Section, Dallas, Tex.
Bychok, Victor (Seis. Party Chief, Atlantic Refining Co.), P. O. Box 1115, Andrews, Tex.
Byerly, Perry (Professor of Seismology), Dept. of Geological Sciences, University of California, Berkeley 4, Calif.
Byers, John W. (Geophysicist, McCollum Exploration Co.), 853 Esperson Bldg., Houston, Tex.

Caan, Albert J. Z. (Geophysicist), c/o Socony-Vacuum Oil Co., Inc., Apartado 246, Caracas, Venezuela, S. A.

Cady, Francis H. (Geophysical Computer, Carter Oil Co.), Box 2104, Billings, Mont.
Calhoun, F. F. (Party Chief, Garrett Exploration Co.), 7015 Hillcrest, Dallas 5, Tex.
Campbell, David B., Jr., 2804 N. Robinson, Apt. 2, Oklahoma City, Okla.
*Campbell, E. L. (Seismic Party Chief, National Geophysical Co.), 1404 Tower Pet. Bldg., Dallas 1, Tex.
Campbell, F. F. (Supervisor, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
*Campbell, H. H. (Observer, Republic Exploration Co.), Mission, Tex.
Carlton, Dave P. (Chief Geophysicist, Humble Oil & Refining Co.), 856 Humble Bldg., Houston 2, Tex.
Carr, G. W. (Owner, Carr Geophysical Co.), 1536 Commerce Bldg., Houston 2, Tex.
Carr, John (Geophysicist), c/o Shell Oil Co. of Egypt, Cairo, Dgypt.
Carson, Roe W. (Geophysical Computer, Garrett Exploration Co.), 900 Pipkin Street, Beaumont, Tex.
Carter, Ray K., 9044 Burton Way, Beverly Hills, Calif.
Carter, R. W. (Jr. Party Chief, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Cash, Harvey, Jr. (Supervisor), c/o Texas Co., Geoph. Div., Box 2332, Houston, Tex.
Caster, E. L. (Supt. Land & Geology Dept.), c/o Arkansas Natural Gas Corp., Box 1734, Shreveport, La.
Cathey, John A. (Geophysicist, Seaboard Oil Co.), 1303 Continental Bldg., Dallas, Tex.
Cerveny, Philip F. (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
*Chang, Tun Yin (Interpreter, Geophysical, Atlantic Refining Co.), 2628 E. 14th St., Tulsa, Okla.
*Chapman, C. J. (Seis. Computer, Imperial Oil Ltd.), 1021 19th Ave. N. W., Calgary, Alberta, Canada.
Charrin, P. J. D. (President, Universal Exploration Co.), 2044 Richmond Rd., Houston, Tex.
Charske, Charles J. (Research Geophysicist, Humble Oil & Refining Co.), 114 Brace St., Houston 12, Tex.
Cheney, M. G. (President, Anzac Oil Corp.), Coleman, Tex.
Chesher, C. E. (Seismologist), c/o Canadian Esploration Co., 216 Lancaster Bldg., Calgary, Alberta, Canada.
Child, V. E. (Party Chief, American Exploration Co.), 687 31st St., Oakland 9, Calif.
Christie, Norman J. (Supervisor), c/o United Geophysical Co., 822 Thompson Bldg., Tulsa 3, Okla.
Clark, George B. (Computer, Independent Exploration Co.), 901 Esperson Bldg., Houston, Tex.
Clark, R. C. (Geophysical Supervisor, Carter Oil Co.), Box 2104, Billings, Mont.
Clark, R. W. (Chief Geologist, Western Gulf Oil Co.), 1260 Subway Terminal Bldg., Los Angeles, Calif.
Clark, W. C., (address unknown).
Clark, William W. (Geophysical Supervisor, Carter Oil Co.), 494 Ockley Drive, Shreveport, La.
Clayton, Neal (Seismic Party Chief, Republic Exploration Co.), 2600 N. W. 12th St., Oklahoma City, Okla.
Clement, Paul F. (Geophysicist, Western Gulf Oil Co.), 401 19th St., Bakersfield, Calif.
Clewell, Dayton H. (Asst. Director Field Research Labs.), c/o Magnolia Petroleum Co., Box 900, Dallas, Tex.
Clifford, O. C., Jr. (Chief Geophysicist, Atlantic Refining Co.), Box 2819, Dallas, Tex.
Clifton, R. L. (Geologist & Engineer, Champlin Refining Co.), 1703 E. Maple, Enid, Okla.
Cline, A. F. (Field Supervisor), c/o C. H. Frost Gravimetric Surveys, 1859½ So. Boston, Tulsa, Okla.
*Coan, G. B. (Chief Observer, Geophysical Research Corp.), Box 451, Aztec, New Mex.
Cobb, Howard L. (Gravity Interpreter, Atlantic Refining Co.), Box 2819, Dallas, Tex.
Cody, C. C. (Party Chief), c/o Seismograph Service Corp. of Dela., Apartado 1488, Caracas Venezuela, S. A.
Coffin, R. Clare (Geophysical Co-ordinator), c/o Stanolind Oil & Gas Co., Box 591, Tulsa 2, Okla.

Cohick, Kenneth S. (Seismologist, Shell Oil Co., Inc.), 527 Forum Building, Sacramento 14, Calif.
Coit, R. B. (Partner, Coit Bros.) 1509 Magnolia Bldg., Dallas, Tex.
Cole, J. Gordon (Consulting Geologist), 1735 Golden Gate Ave., Los Angeles 26, Calif.
Cole, R. C. (Party Chief, Carr Geophysical Co.), 1536 Commerce Bldg., Houston 2, Tex.
†Collett, L. S. (Student), c/o Prof. J. H. Hodgson, University of Toronto, Geophysics Dept., Toronto, Ontario, Canada.
Collingwood, Douglas M. (Geological and Petroleum Engineer), c/o Sun Oil Co., Box 2880, Dallas, Tex.
Colvin, C. E. (Observer, Geotechnical Corp.), 2008 Main St., Miles City, Mont.
Conant, E. E. (Supervisor, United Geophysical Co.), 2630 E. 23rd St., Lubbock, Tex.
Conklin, Glenn M. (Research Interpreter, Sun Oil Co.), 2605 Amarillo, Beaumont, Tex.
*Conley, H. R. (Geophysicist and Technician, American Exploration Co.), 204 N. Chestnut St., LaFayette, La.
Connell, Joe E. (Chief Computor, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Conover, George E. (Field Operations Engineer, Magnolia Petroleum Co.), 525 Davis St., Garland, Tex.
P. P. Conrad (Asst. Chief Geophysicist), c/o Socony-Vacuum Oil Co., Aptdo. 246, Caracas, Venezuela, S. A.
Cook, D. E. (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Cook, Kenneth L. (Geophysicist, U. S. Geological Survey), Box 9235, University Station, Reno, Nev.
Cook, Paul C. (Seis. Party Chief, Keystone Exploration Co.), 2813 Westheimer Rd., Houston, Tex.
†Coolbaugh, David F. (Student, Colorado School of Mines), 1700 Maple St., Golden, Colo.
Cooley, E. H. (Research Engineer, Stanolind Oil & Gas Co.), R. R. #1, Box 384, Tulsa, Okla.
Cooper, Jack R. (Research Engineer, Stanolind Oil & Gas Co.), 2534 S. Delaware Pl., Tulsa 5, Okla.
*Copeland, R. J. (Gravity Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Corbin, A. P., Jr., 1636 Amelia Street, New Orleans, La.
Cornett, J. R. (Computer), c/o Seismograph Service Corp., Box 228, Cairo, Egypt.
Cornish, Lou G. (Supervisor of Interpretation, Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
Cortes, Henry C. (Asst. Mgr. Land & Exploration Depts., Magnolia Petroleum Co.,) 4328 Windsor Parkway, Dallas 5, Tex.
Coryn, Francis R. (Geophysical Supervisor, Texas Co.), P. O. Box 2420, Tulsa 2, Okla.
Couch, Robert G. (Seismologist), c/o Socony-Vacuum Oil Co., Apartado 246, Caracas, Venezuela, S. A.
Courtier, William Henry (Asst. Chief Geophysicist), Geophysical Dept., Phillips Petroleum Co., Bartlesville, Okla.
Courtney, E. A. (Consulting Geologist), P. O. Box 471, Hammond, La.
*Courtney, C. J. (Party Chief, California Company), 1610 Water St., Boulder, Colo.
Cowles, Laurence G. (Research Geophysicist, Superior Oil Co.), 2819 Jarrard, Houston 5, Tex.
Craig, Robert L. (Research Engineer), c/o Carter Oil Co., Box 801, Tulsa, Okla.
Crain, R. Ashton (Party Chief, Texas Seismograph Co.), 1711 Polk St., Wichita Falls, Tex.
Cram, Ira H. (Asst. to Chief Geologist), c/o Pure Oil Co., 35 E. Wacker Drive, Chicago 2, Ill.
Crary, Albert P. (Geophysicist), Watson Laboratories, A. M. C., WLERL-4, Red Bank, N. J.
*Crary, Donald (Seismologist, Sohio Petroleum Co.), 614 Neils Esperson Bldg., Houston, Tex.
*Crary, Donald (Seismologist, Sohio Petroleum Co.), 614 Neils Esperson Bldg., Houston, Tex.

Crawford, John M. (Control Geophysicist, Continental Oil Co.), 1105 S. 9th St., Ponca City, Okla.
Crawford, Paul D. (Consulting Geophysicist), 1421 Milam Bldg., San Antonio 5, Tex.
Crawford, Weldon L. (District Supervisor, Petty Geophysical Co.), Box 2061, San Antonio, Tex.
*Creighton, Roger B. (Geologist, California Co.), 1818 Canal Bldg., New Orleans 12, La.
Crenshaw, C. C. (Core Drill Supt.), c/o Phillips Petroleum Co., Bartlesville, Okla.
Crider, Lewis C. (Field Geologist), c/o California Co., 1818 Canal Bldg., New Orleans, La.
*Cronin, Eugene J., 5240 41st St., N. W., Washington, D. C.
Cronin, Stewart (Geologist, Pure Oil Co.), Box 1398, Billings, Mont.
Crowell, J. H. (Vice-President, Crowell & Steele, Inc.), 3416 Ella Lee Lane, Houston, Tex.
*Crump, Oscar M. (Computer, Atlantic Refining Co.), Box 2819, c/o Geophysical Section, Dallas, Tex.
Culbertson, J. A. (Division Geologist, Continental Oil Co.), 610 Oil & Gas Bldg., Houston, Tex.
Culp, Harold A. (Party Chief, Brown Geophysical Co.), General Delivery, Mount Vernon, Ore.
Curnutt, F. E. (Independent), P. O. Box 11, Kentwood, La.

Dahlberg, Jack K. (Magnetic Supervisor, Ned. Kol. Petr. Co.), 1704 S. Madison, Tulsa, Okla.
Dahlberg, Robert S., Jr. (Research Physicist), c/o Creole Petroleum Corp., Apartado 889, Caracas, Venezuela, S. A.
Dahm, Cornelius G. (Chief Seismologist, Magnolia Petroleum Co.), 3625 Bryn Mawr Drive, Dallas 5, Tex.
*Damon, Everett F. (Chief Observer, Amerada Petroleum Corp.), Box 910, Duncan, Okla.
Dana, R. H. (Supervisor), c/o Southern Geophysical Co., Sinclair Bldg., Ft. Worth, Tex.
*Dausman, R. H. (Owner, Harrison Equipment Co.), 3703 Jardin St., Houston 5, Tex.
Davidson, George B. (Party Chief, Magnolia Petroleum Co.), Box 900, Dallas, Tex.
Davies, Nathan C. (Consulting Geologist and Engineer), Box 143, Robinson, Ill.
Davies, Richard (Chief Geophysicist), c/o Geological Dept. Anglo-Iranian Oil Co., Ltd., Britannic House, Finisbury Circus, London EC2, England.
Davis, D. R. (Magnetometer Operator, Texas Co.), 317 S. Detroit, Tulsa 3, Okla.
Davis, Donald M. (Scout, Union Oil Co. of Calif.), 1700 Nineteenth St., Bakersfield, Calif.
Davis, Donald M. (Division Geologist), c/o Pure Oil Co., Box 239, Houston, Tex.
Davis, L. A. (Seismologist, Petty Geophysical Engineering Co.), Box 2061, San Antonio 6, Tex.
Davis, Rollin E. (Party Chief, Southern Geophysical Co.), 1003 Sinclair Bldg., Ft. Worth 2, Tex.
Dawson, Herbert M. (Foreign Supervisor, Petty Geophysical Engineering Co.), Box 2061, San Antonio, Tex.
*Day, Charles E. (Research Engineer), c/o Geophysical Research Corp., 2607 N. Boston Pl., Tulsa, Okla.
Deacon, L. E. (Vice-President, Grapevine Milling Co.), Grapevine, Tex.
‡DeGolyer, E. L. (Senior Partner, DeGolyer & MacNaughton), 1000 Continental Bldg., Dallas 1, Tex.
DeGood, R. G. (Party Manager, Gulf Research & Development Co.), 201 Lincoln, Loveland, Colo.
Dehlinger, Peter (Seismologist), c/o Shell Oil Co., Inc., P. O. Box 720, Casper, Wyo.
DeLoach, Edward L. (Dist. Geophysicist, Atlantic Refining Co.), 1742 Milam Bldg. San Antonio, Tex.
*Del Rio M., Alejandro (Chief Geologist, Colombian Govt. Geological Survey), Calle 53, No. 14-32, Bogota, Colombia, S. A.

Deming, J. H. (Geophysicist), c/o Venezuelan Atlantic Refining Co., Apartado No., 893, Caracas, Venezuela, S. A.
Denning, Wayne H. (Supervisor, United Geophysical Co.), Rua Uruguaiana, 118, 9 Andar, Rio de Janeiro, Brazil, S. A.
Dennis, Terence E. (Party Chief, Superior Oil Co.), Box 510, Midland, Tex.
Deussen, Alexander (Independent Consulting Geologist), 1006 Shell Bldg., Houston 2, Tex.
*Dexter, Laurence N. (Party Chief, Atlantic Refining Co.), Box 275, Three Rivers, Tex.
DeWoody, D. A. (Seis. Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Di Giulio, Fred J. (Party Chief, Western Geophysical Co.), Box 346, Party 18, Gulfport, Miss.
*Dissler, Ernst (Seis. & Magnetics Computer, Cities Service Oil Co.), 724 Seneca, Bartlesville, Okla.
Diveley, Paul R. (Seis. Party Manager, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Dix, C. Hewitt (Vive-President, c/o United Geophysical Company, 595 E. Colorado, Pasadena 1, Calif.
*Dobrick, Edward G., Jr. (District Geologist, California Co.), 1818 Canal Bldg., New Orleans 12, La.
Dobrin, Milton B. (Physicist, Naval Ordnance Lab.), 3510 A St. S. E., Washington, D. C.
Dobyns, D. R. (Geophysical Supervisor, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Dodd, Lavon C., 3430 Rosedale St., Houston 4, Tex.
Doll, H. G. (Director of Research, Schlumberger Well Surveying Corp.), Box 2175, Houston 1, Tex.
*Doll, W. R. (Seismologist, Seismograph Service Corp.), 509 W. Texas Ave., Midland, Tex.
Donnally, Chester J. (Vice-President, Western Geophysical Co.), 1102 First National Bank Bldg., Dallas, Tex.
Donnelly, V. T. (Gravity Meter Supervisor, Arkansas Fuel Oil Co.), 730 W. Lynwood, San Antonio 1, Tex.
Donohoo, H. V. W. (Research Engineer, Columbia University, Geology Dept., New York 27, N. Y.
Doolittle, Russell C. (Interpreter, Gulf Research & Development Co.), Box 51, R. R. #1, Pittsburgh 21, Pa.
Dorris, James E. (Acting Manager, Seismograph Service Corp. of Dela.), Apartado 1488, Caracas, Venezuela, S. A.
Dortch, Willis R., Jr. (Seismic Computer), c/o Socony-Vacuum Oil Co., Seismic Party 2, Puerto Wilches, Colombia, S. A.
Doss, Carson L. (Director of Instrumentation, Colorado School of Mines), Box 541, Golden, Colo.
Douglas, Norvel (Owner, Douglas Engineering Co.), 7114 Hines Blvd., Dallas 9, Tex.
Drennan, William A., 331 Arvin St., Bakersfield, Calif.
Dresbach, C. H. (Asst. Chief Geologist & Geophysical Co-ordinator), Western Gulf Oil Co., 1260 Subway Terminal Bldg., Los Angeles 13, Calif.
Dudley, Raymond W. (Geophysical Co-ordinator, Pure Oil Co., Box 2107, Ft. Worth, Tex.
Dugan, Albert F. (Gravity Computer, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
†Duffner, Ralph T. (Graduate Student, Colorado School of Mines), 2801 E. Colfax Ave., Denver 6, Colo.
Duller, Charles E. (Vice-President & Treasurer, Well Surveys, Inc.), 624 E. 4th St., Tulsa, Okla.
*Dunaven, W. A. (Computer, Independent Prospecting Co.), Roodhouse, Ill.
Dunaway, J. H. (Senior Research Geophysicist, Humble Oil & Refining Co.), 258 Humble Bldg., Houston 2, Tex.
Dunbar, R. O. (Party Chief), c/o Phillips Petroleum Co., Box 1926, San Benito, Tex.

Dundon, Robert F. (Computer, Geophysical Service, Inc.), Box 617, Bakersfield, Calif.
Dunlap, A. D. (Party Chief, Independent Exploration Co.), 901 Esperson Bldg, Houston 2, Tex.
Dunlap, Robert C. (District Supervisor, Geophyiscal Service, Inc.), 1009 Pacific Southwest Bldg., Fresno, Calif.
Durham, Charles A. (Geologist, Humble Oil & Refining Co.), Box 1600 Midland, Tex.
Duty, Robert S., Jr. (Asst. Seis. Chief), Humble Oil & Refining Co., 805 Humble Bldg., Houston, Tex.
Dyk, Karl (Seismograph Supervisor, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.

Eberts, A. G. (Party Chief, Texas Co.), Box 2332, Houston 1, Tex.
Eby, A. N. (Seis. Party Chief, Superior Oil Co.), Box 63, Bellaire, Tex.
Eby, J. Brian (Consulting Geologist), 1404 Esperson Bldg., Houston 2, Tex.
Eckhardt, E. A. (Vice-President, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Edmonson, Carl L. (Gravity Meter Party Chief, Carter Oil Co.), Box 801, Tulsa, Okla.
Edmonston, William J. (Computer, Geotechnical Corp.), Box 7166, Dallas, Tex.
Egan, Daniel G. (Geophysicist), Geophysical Dept., International Pet. Co., Apartado 1081, Lima, Peru, S. A.
Eichelberger, A. M., Jr. (Senior Physicist, Magnolia Petroleum Co.), 1310 So. Harlandale Ave., Dallas 16, Tex.
Eisler, Joseph D. (Technical Group Supervisor, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.
Elkins, Thomas A. (Geophysicist, Gulf Research & Development Co.), 3255 Parkview Ave., Pittsburgh 13, Pa.
Ellis, L. G. (Chief of Seismograph Dept.), c/o Sun Oil Co., Beaumont, Tex.
Ellsworth, T. P. (Chief Geophysicist), c/o Richfield Oil Corp., 560 Haberfelde Bldg., Bakersfield, Calif.
Elms, R. G. (Chief Geophysicist), Union Sulphur Company, Sulphur, La.
Emanuel, Vincent (Asst. to President, Grant Oil Tool Co.), 2330 Hillcrest Drive, Los Angeles, Calif.
England, C. M. (Geophysicist, National Geophysical Co.), 906 Electra, Longview, Tex.
English, Walter A. (Independent Geologist), 114 So. Beaudry Ave., Los Angeles, Calif.
Enslin, J. F. (Sr. Geophysicist, Geoloigcal Survey), Box 401, Pretoria, Union of South Africa.
Epperson, R. S., Address unknown.
Erdahl, William M. (Geophysicist, Skelly Oil Co.), 1644 N. Boston Pl., Tulsa, Okla.
*Ergin, Kazim, c/o M. T. A. Enstitusu, Ankara, Turkey.
Erickson, Anton (Physicist, Naval Ordnance Lab.), 9131 Subdury Rd., Silver Spring, Md.
Erickson, E. L. (Geophysicist, Continental Oil Co.), 700 Edison Bldg., Los Angeles 13, Calif.
Ericson, Harry B. (Seismograph Interpreter, Cities Service Oil Co.), 1504 Dewey Bartlesville, Okla.
*Ervin, Lynn D. (Party Chief, Stanolind Oil & Gas Co.), Box 308, Marlowe, Okla.
Etherington, Thomas J. (District Geologist, Standard Oil of Calif.), 3163 W. Laurelhurst Dr., Seattle, Wash.
Evans, Julian F. (Research Engineer, Stanolind Oil and Gas Co.), 2964 S. Cincinnati, Tulsa 5, Okla.
Everitt, James (Computer, Geophysical Service, Inc.,) Box 101, Sidney, Ill.
Evjen, H. M. (Technical Director, The Eiflex Co.), Box 453, Ruidoso, New Mex.
*Evrard, Pierre (Asst. Professor of Geology, University of Liege), 54 rue du Taciturne, Brussels, Belgium.
Ewing, Maurince (Assoc. Prof. of Geology), Department of Geology, Columbia University, New York 27, N. Y.

Fain, Edgar A. (Industrial Methods Engineer, National Housing Agency), 913 North Wayne St., Arlington, Va.
Falkenhagen, H. M. (Supervisor, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.

Farmilo, Alfred W. (Geologist & Geophysicist), c/o The California Standard Co., 700 Lancaster Bldg., Calgary Alberta, Canada.
Farren, Paul (Supervisor, National Geophysical Co.), 2802 Pine St., Texarkana, Ark.-Tex.
Farrow, B. D. (Seis. Party Chief, Geotechnical Corp.), 1702 Tower Petroleum Bldg., Dallas 1, Tex.
Faul, Henry (Research Associate, Laboratory of Nuclear Science & Engineering), c/o Mass. Inst. of Tech., Cambridge 39, Mass.
Feagin, Frank J. (Research Specialist, Humble Oil & Refining Co.), 252-B Humble Bldg., Houston, Tex.
Fearon, R. E. (Research Engineer, Stanolind Oil & Gas Co.), 1430 S. Terrace Dr., Tulsa, Okla.
Feather, V. G. (Geologist & Seismologist, Honolulu Oil Corp.), 2415 27th St., Lubbock, Tex.
Fenwick, Willis H. (Partner, Intermountain Exploration & Engineering Co.), Box 319, Casper, Wyo.
Ferber, Herbert J. (Geophysicist), c/o Gulf Research & Development Co., Box 375, La Junta, Colo.
Ferguson, J. G. (Gravity Supervisor, Western Geophysical Co.), Box 596, Natchez, Miss.
Ferguson, J. B. (Geophysicist, Apache Exploration Co.), Box 1711, Houston 1, Tex.
*Ferguson, Joe L. (Party Chief, Brown Geophysical Co.), P. O. Box 6005, Houston 6, Tex.
Ferguson, John L. (Geologist), Amerada Petroleum Corp., Box 2040, Tulsa 2, Okla.
Ferris, Craig (Partner, E. V. McCollum Co.), 2958 S. Cincinnati St., Tulsa 5, Okla.
Fetzer, E. L. (Party Chief, National Geophysical Co.), 1404 Tower Petroleum Bldg., Dallas, Tex.
Fillippone, W. R. (Chief Computer), c/o United Geophysical Co., 595 E. Colorado St., Pasadena 1, Calif.
Fink, Paul O. (Geophysicist, Gulf Research & Development Co.), 1320 Leishman Ave., New Kensington, Pa.
*Finley, R. K. (Observer, Seismograph Service Corp.), c/o Basra Petroleum Co., Seiscor, Party #5, Basra, Iraq.
Finn, Robert S. (Research Engineer, Seismograph Service Corp.), 927 S. Toledo, Tulsa 4, Okla.
Fisch, W. (Chief of Geophysical & Geological Bureau), Stockerstrasse 43, Zurich 2, Switzerland.
Fischer, L. F. (Geophysicist, Sohio Petroleum Co.), Box 1667, Shreveport, La.
Fischer, Leon (Seismologist, Shell Oil Co.), Box 457, Holly, Colo.
Fishback, Joseph W. (Gravity Meter Supervisor, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.
Fisk, Frank K. (Vice-President, Exploration Surveys Inc.), 1914 Harwood St., Dallas, Tex.
Fitch, A. A. (Party Chief), c/o Seismograph Service, Ltd., 3a London Wall Bldg., London EC2, England.
Flude, John Wm. (Geophysicist), 3039 Locke Lane, Houston 6, Tex.
Fohs, F. Julius (Consulting Geologist), 433 Esperson Bldg., Houston 2, Tex.
*Foote, W. L. (Seis. Computer), c/o Superior Oil Col, Box 1457, Levelland, Tex.
Forward, Fred (Party Chief), c/o Phillips Petroleum Company, Box 292, Lamesa, Tex.
Foster, G. A. (Consulting Geophysicist), 2531 E. 3rd St., Tulsa, Okla.
Franks, W. E. (Chief Geophysicist), Exploration Dept., Creole Petroleum Corp., Apartado 1329, Caracas, Venezuela, S. A.
Freel, J. F. (Geophysicist, Research Explorations, Inc.), Box 2583, West Jackson 117, Miss.
Freeman, Lawrence I. (President), Heiland Exploration Co., 630 Giddens-Lane Bldg., Shreveport, La.
*Friendly, Jack L. (Director of Maintenance & Assemble Dept., Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
Frosh, Alex (Sr. Research Geophysicist, Humble Oil & Refinding Co.), Box 2180, Houston 1, Tex.

Frost, Holloway (Chief Geophysicist), c/o Socony-Vacuum Oil Co., 62 Sharia Krakeim Pasha, Cairo, Egypt.
Frost, Noel (Asst. Instrument Supervisor), c/o Seismograph Service Corp., Box 1590 Tulsa, Okla.
Frowe, Eugene (Physicist, Robert H. Ray Co.), 2535 Dunstan Rd., Houston 5, Tex.
Fruehling, S. W. (Party Chief, Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
Fu, Ch'eng Yi (Asst. Professor of Geophysics), Dept. of Geophysics, Calif. Inst. of Tech., Pasadena, Calif.
Fuller, O. K., Jr. (Party Chief, United Geophysical Co.), 2655 Las Lunas St., Pasadena 8, Calif.
Futral, John E. (Party Chief, Texas Company), Geophysical Div., Box 2332, Houston, Tex.

Gabriel, V. G. (Consulting Geologist & Geophysicist), 447 S. Hope St., Los Angeles 13, Calif.
Gaby, Ewin D. (Supervisor, Geophysical Service Inc.), 1611 Devine St., Jackson, Miss.
Gaby, Phil P. (Consulting Geophysicist, Standard Oil Co. of Calif.), 5649 Buena Vista Ave., Fresno, Calif.
*Gaither, Jerrel W. (Party Chief, Atlantic Refining Co.), Box 2819, Dallas 1, Tex.
Gallaway, Roy Lee (Observer, Texas Co.), Box 551, Donaldsonville, La.
Galloway, John O. (Executive Vice-President, California Standard Co.), 700 Lancaster Bldg., Calgary, Alberta, Canada.
Gallie, J. F. (Sr. Geologist, Cabot Carbon Co.), Box 1101, Pampa, Tex.
Gardner, Louis W. (Geophysicist, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Garber, Allen J., Jr. (Party Chief, United Geophysical Co.), P. O. Box 1200, Santa Barbara, Calif.
Gardner, Derry H. (Asst. Division Head, Humble Oil & Refining Co.), 260 Humble Bldg., Houston 1, Tex.
*Garner, J. P. (Manager, Oil Explorations, Inc.), 604 McBirney Bldg., Tulsa, Okla.
Garpner, E. U. (Geophysicist, C. H. Frost Gravimetric Surveys, Inc.), 2633 E. 19th St., Tulsa 4, Okla.
Garrett, Geo. A. (Head of Theoretical Analysis Dept., Carbide & Carbon Chemical Corp.), 108 Moylan Lane, Oak Ridge, Tenn.
Garrett Melvin M. (President, Garrett Exploration Co.), 1423 Republic Bank Bldg., Dallas, Tex.
Garrett, William M. (Geophysicist), 4215 Keever Ave., Long Beach, Calif.
Gayman, William H. (Research Engineer, Northrop Aircraft, Inc.), 223 W. Ash St., Burbank, Calif.
Gealy, Wendell, B. (Geologist, Gulf Oil Corp.), Box 1166, Pittsburgh 30, Pa.
Gemmer, R. W. (Asst. Chief Geophysicist, Carter Oil Co.), Box 801, Tulsa, Okla.
Gemmill, Edward J., (Division Geophysicist, Cities Service Oil Co.), 1440 Mellie Esperson Bldg., Houston 2, Tex.
*George, Fred W. (Party Chief, Brown Geophysical Co.), Route 1, Livingston, Tex.
Gerdes, C. H. (Geophysicist, United Geophysical Co.), 595 E. Colorado St., Pasadena, Calif.
Germain-Jones, D. T., 2a, Appletongate, Newark, Notts., England.
Geyer, Richard A. (Research Geophysicist, Humble Oil & Refining Co.), Room 201 Humble Bldg., Box 2180, Houston, Tex.
Geyer, Robert L. (Computer), c/o Seismograph Service Corp. of Dela.), Apartado 1488, Caracas, Venezuela, S. A.
Gibbon, H. A. (Chief Geophysicist), c/o Standard Vacuum Oil Co., 26 Broadway, New York 4, N. Y.
Gibson, G. D. (Geophysicist, British American Oil Prod. Co.), Box 2649, Tulsa, Okla.
Gibson, M. O. (Administrative Assistant), c/o Shell Oil Co., Inc. Exploration Dept., Box 1509, Midland, Tex.
Giezendanner, S. S. (Seis. Party Chief, Texas Co.), Box 2332, Houston 1, Tex.
*Giles, Ernest P. (Engineer, Petty Geophysical Engineering Co.), 317 Sixth St., San Antonio, Tex.
Gilkison, Don (Seis. Party Manager, Gulf Research & Development Co.), P. O. Box 802, Cody, Wyo.

Gilliam, J. T. (Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
Gilliland, J. R. (Party Chief, General Geophysical Co.), 2514 Gulf Bldg., Houston 2, Tex.
Gillin, John A. (President, National Geophysical Co.), 4501 N. Versailles, Dallas, Tex.
Gilmour, Andrew (Supervisor, Geophysical Research Corp.) Box 2040, Tulsa 2, Okla.
Gilmore, John A. (Geophysicist, Universal Exploration Co.), 2044 Richmond, Houston, Tex.
Gilmore, Marion H. (Research Geophysicist), Hurricane Weather Central, NAS, Ad. Bldg. Opa-Lcka, Miami, Fla.
Giltinan, G. M. (Administrative Advisor & Director, Seismograph Service Corp.), 709 Kennedy Bldg., Tulsa, Okla.
Glover, Robert H. (Party Chief), c/o Superior Oil Co., Box 422, El Reno, Okla.
Godefroy, C. (Geological Engineer, A. E. Verner), Apt. 207, 120 Oriole Parkway, Toronto 12, Ontario, Canada.
*Godell, John J. (Seismic Computer, Magnolia Petroleum Co.), Box 900, Dallas, Tex.
Goebel, Lawrence A. (District Geologist, Carter Oil Co.), Drawer 1739, Shreveport, La.
Goldstone, Frank (Chief Geophysicist), c/o Shell Oil Co., Inc., Box 2099, Houston 1, Tex.
Gore, Robert F. (Computer, Geophysical Service, Inc.), Miller Grove, Tex.
Goss, Henry V. (Geophysicist), c/o Humble Oil & Refining Co., 861 Humble Bldg., Houston 1, Tex.
Gould, Martin J., address unknown.
Granberry, Harold E. (Gravity Field Supervisor, Magnolia Petroleum Co.), Box 900, Dallas, Tex.
Grange, Donald C. (Party Chief, Brown Geophysical Co.), Box 6005, Houston 6, Tex.
*Graves, Earl (Computer, Atlantic Refining Co.), Box 2819, Dallas, Tex.
Gray, William R. (address unknown).
Green, Cecil H. (Vice-President, Geophysical Service Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Green, W. G. (President, Engineering Laboratories, Inc.), 624 E. 4th St., Tulsa, Okla.
Greenlee, Paul (Seismologist, Petty Geophysical Engineering Co.), Box 807, Lovington, New Mex.
Gregory, Carter H. (Geophysicist), c/o Shell Oil Co., Box 2099, Houston, Tex.
Griffin, I. M. (Vice-President, General Geophysical Co.), 2445 Stanmore Drive, Houston 6, Tex.
Grimm. G. A. (Party Chief, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Grizzell, Edward I. (Party Chief, Independent Exploration Co.), c/o Iraq Petroleum Co., Box 309 Haifa, Palestine.
Grossling, Bernado F. (Civil & Electrical Engineer), c/o Corporacion de Fomento, Punta Arenas, Chile, S. A.
Gsell, R. N. (Gravity Co-ordinator, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Guimaraes, Helio P. (Geophysicist, Conselho Nacional de Petroleo), Caxia Postal 284, Ponta Grossa, Parana, Brazil, S. A.
Gulmon, G. W. (Geologist, California Co.), Box 360, Natchez, Miss.
Gunn, J. E. (Party Manager, Gulf Research & Development Co.), P. O. Drawer 2038, Pittsburgh 30, Pa.
Guseman, L. F. (Exec. Vice-President, American Exploration Co.), 204 N. Chestnut St., Lafayette, La.
Gutenberg, Beno (Professor of Geophysics, California Inst. of Tech.), Seismological Laboratory, 220 N. San Rafael Ave., Pasadena 2, Calif.
Guyod, H. (Well Logging Consultant), 730 1st National Bank Bldg., Houston, Tex.

Haber, A. F. (Party Chief), c/o Continental Oil Co., Geophysical Dept., Ponca City, Okla.
Hafner, W. (Geophysicist), c/o Shell Oil Co., 1807 Shell Bldg., Houston, Tex.
Haggerty, Patrick E. (Gen. Mgr. Lab. & Mfg. Div., Geophysical Service, Inc.), 2831 Northwest Highway, Dallas 9, Tex.
*Hale, C. Russell (Co-ordinator of Foreign Operations, United Geophysical Co.), 595 E. Colorado St., Pasadena 1, Calif.

Hale, Francis A. (Seismologist), c/o Richmond Exploration Co., Sociedad a Cameljo 16, Caracas, Venezuela, S. A.
Hales, Frederick W. (Geophysicist, Anglo-Iranian Oil Co., Ltd.), c/o D'Arcy Exploration Co., Box 1, Southwell Nottinghamshire, England.
Hall, T. O. (Vice-President, General Geophysical Co.), 2514 Gulf Bldg., Houston, Tex.
Halsey, Raymond E. (Computer, Petty Geophysical Engineering Co.), Box 91, Baton Rouge, La.
Hamil, A. B. (Owner), Marine Exploration Co., 3200 West Dallas, Houston 6, Tex.
Hamilton, W. Brooke (Independent Lease Broker), 2420 Dryden Rd., Houston, Tex.
*Hamm, John G. (Surveyor, Independent Exploration Co.), 901 Esperson Bldg., Houston, Tex.
Hammer, Sigmund I. (Head of Gravity Interpretation Section, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
†Hammett, John P. (Student, University of Tulsa), 1912 S. Florence Pl., Tulsa 4, Okla.
*Hammial, LeRoy Leonard (Computer, Independent Exploration Co.), Box 72, Breckenridge, Tex.
Hammitt, Philip (Geophysical Supervisor), c/o Venezuelan Atlantic Refining Co., Apartado 893, Caracas, Venezuela, S. A.
Hannum, Robert C. (Information-Education Officer, U. S. Army), I. & E Sect. 463 AAFBU, Geiger Field, Wash.
Handley, E. J. (Vice-President, Seismograph Operations, Century Geophysical Corp.), 2935 S. Cincinnati, Tulsa, Okla.
Happel, Henry H. (Laboratory Director, Seismic Explorations, Inc.), Box 6248, Houston, Tex.
*Harbach, Robert G. (Junior Computer, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Harding, Maynard W. (Personnel Manager), United Geophysical Co., 595 E. Colorado St., Pasadena, Calif.
Harding, R. N. (Party Chief, Texas Company), P. O. Box 1283, Hattiesburg, Miss.
Hardy, Willis W. (Chief Geophysicist), c/o Socony-Vacuum Oil Co., Room 1700, 26 Broadway, New York N. Y.
Hargis, A. V. (Seis. Party Chief, Stanolind Oil & Gas Co.), Birthright, Tex.
*Harkey, W. J. (Party Chief, National Geophysical Co.), Box 249, Rankin, Tex.
Harkins, Curtis P. (Party Chief, Independent Exploration Co.), 901 Esperson Bldg., Houston, Tex.
Harkness, T. O. (Geophysicist, Tomlinson Geophysical Service), 6319 Velasco St., Dallas, Tex.
Harlton, Bruce H. (Research Geologist, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Harris, B. A. (Party Chief, Geophysical Service, Inc.), Box 1512, McAllen, Tex.
Harris, J. A. (Geologist), c/o California, Co., 1818 Canal Bldg., New Orleans, La.
Harris, John (Chief Computer, Atlas Exploration Co.), 1911 W. Alabama, Houston, Tex.
*Harris, Phil C. (Electrical Engineer, North American Geophysical Co.), 1854 Kipling, Houston, Tex.
Harris, Sidon (President, Southern Geophysical Co.), 1003 Sinclair Bldg., Ft. Worth, Tex.
*Hart, M. M. (Seismograph Computer), c/o Socony-Vacuum Oil Co. de Colombia, Cr. Mr. Puccini, Apartado Aereo 342, Barranquilla, Colombia, S. A.
Hartline, Ralph E. (Research Engineer, Stanolind Oil & Gas Co.), 1943 S. College Tulsa 4, Okla.
Harvey, Castle J. C. (District Seismologist), c/o Atlantic Refining Co., Box 2407, West Jackson, Miss.
Haskell, Norman A. (Chief Geophysicist), Geophysical Lab., United States Smelting & Refining Co., 1126 Boylston St. Boston, Mass.
Hastings, W. K. (Gravimeter Party Manager, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Hathaway, Claude M. (Chief Engineer), c/o Hathaway Instrument Co., Box 4178, Denver, Colo.
*Hathaway, Joseph G. (Geologist), c/o General Petroleum Corp., #6 Crites Bldg., 1832 Eye St., Bakersfield, Calif.

Hathaway, M. S. (Asst. Dist. Seismologist, Atlantic Refining Co.), Box 2407, Jackson, Miss.
*Hawes, Julian (Sr. Geologist, Stanolind Oil & Gas Co.), 1716 So. Main, Tulsa, Okla.
Hawkes, H. E. (Geologist), U. S. Geological Survey, Washington 35, D. C.
Hawkins, J. F. (Research & Development Director, Seismograph Service, Inc.), 1612 S. Evanston, Tulsa, Okla.
Hawthorne, Woodrow W. (Party Chief, Atlantic Refining Co.), P. O. Box 151, Lucedale, Miss.
Haynes, C. J. (Geoph. Research, Humble Oil & Refining Co.), 206 Humble Bldg., Houston, Tex.
Hays, Clyde L. (Gravity Meter Party Chief, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.
Hazen, George H. (Geophysicist in Charge), c/o Socony-Vacuum Oil Co., Apartado Nacional 1140, Bogota, Colombia, S. A.
*Head, E. I. (Magnetometer Operator, Gulf Research & Development Co.), Box T-261, Ozona, Tex.
Heald, Charles L. (Seismologist, United Geophysical Co.), 2202 N. Santa Anita, Altadena, Calif.
Heaney, Donald B. (Chief Computer, Western Geophysical Co.), 1321½ West 39th St., Los Angeles 37, Calif.
*Heard, James R. (Computer, American Exploration Co.), 2412 31st St., Lubbock, Tex.
Hearin, R. P. (Seismograph Party Chief, Phillips Petroleum Co.), Arkadelphia, Arkansas.
Heggblom, J. C. (Geophysicist, Gulf Oil Corp.), c/o Bahamas Exploration Co., Ltd., Box 1098, Nassau, Bahamas, B. W. I.
Heiland, C. A. (President, Heiland Research Corp.), Box 360, Denver, Colo.
Heinrichs, W. E., Jr. (Ens, U. S. N. R.), c/o Dir. of Naval Pet. Res., Room 2009, Tempo #2, Washington, D. C.
Heintz, Karl O. (Research Geophysicist, Humble Oil & Refining Co.), 209 Humble Bldg., Houston, Tex.
Hemmi, C. W. (Seismologist, Petty Geophysical Engineering Co.), Box 2061, San Antonio, Tex.
Henderson, Bill (Seis. Party Chief, North American Geophysical Co.), 2626 Westheimer Rd., Houston 6, Tex.
*Henderson, J. B. H. (Owner, Survey Drilling Co.), Box 324, Dallas, Tex.
Henderson, M. R. (Party Chief, General Geophysical Co.), 2514 Gulf Bldg., Houston 2, Tex.
Henderson, Ross (Party Chief, Geophysical Service Inc.), 1311 (Republic Bank Bldg., Dallas, Tex.
Henquet, R. (Vice-President & General Manager, Schlumberger Well Surveying Corp.), Box 2175, Houston, Tex.
Heroy, William B. (Partner, Beers & Heroy), 6441 Llano St., Dallas, Tex.
Herron, Robert C. (Geophysicist, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Hersey, J. B. (Geophysicist), Woods Hole Oceanographic Institution, Woods Hole, Mass.
Herzenberg, A. J. (Research Geophysicist, Shell Oil Co., Inc.), 2511½ Bellaire Blvd., Houston, Tex.
Hibbler, Alfred J. (Independent Geophysicist), 4414 Woodside Drive, Houston 3, Tex.
Hibbler, M. E. (Party Chief, Texas Co.), Box 2332, Houston, Tex.
Hieatt, Herbert F. (Salesman, Jno. J. Johnson), 507 S. Ervoy St., Dallas, Tex.
*Higgins, G. E. (Exploration Geologist), c/o Trinidad Leaseholds, Ltd. (GPS Division), Pointe-a-Pierre, Trinidad, B. W. I.
Hightower, C. H. (Regional Seismologist, Atlantic Refining Co.), Box 2819, Dallas 1, Tex.
Hilger, C. L., Jr. (Computer, Geophysical Service, Inc.), Box 1147, Dallas, Tex.
Hill, E. Bruce (Research Geophysicist, Humble Oil & Refg. Co.), 206 Humble Bldg., Houston 1, Tex.
Hill, Robert G. (Senior Geophysicist), c/o Texas Petroleum Co., Apartado 267, Caracas, Venezuela, S. A.

*Hill, Roy A. (Geophysicist), 3421 Walnut St., Huntington Park, Calif.
Hillis, Donuil (Chief Geologist), c/o Capital Co., 649 S. Olive St., Los Angeles 14, Calif.
Hinson, Cecil C. (Geophysicist, Universal Exploration Co.), 2044 Richmond, Houston, Tex.
Hintze, A. J. (Chief Geophysicist), c/o Phillips Petroleum Co., Bartlesville, Okla.
Hoard, J. O. (Owner, Hoard Exploration Co.), 931 Esperson Bldg., Houston, Tex.
Hobbs, T. E. (Computer), c/o Socony-Vacuum Oil Co. of Col., Aptdo. Aereo 4034, Aptdo. Nacional 1140, Bogota, Colombia, S. A.
Hodgson, John H. (Asst. Professor of Geophysics, University of Toronto), 49 St. George St., Toronto, Ontario, Canada.
Hoffman, John C. (Seismologist, United Geophysical Co.), 822 Thompson Bldg., Tulsa, Okla.
Hoffman, Malvin G. (Pet. Div. Dept. of State), 3821 W. St. E., Fairfax Village, Washington, D. C.
Hogg, W. B. (Supervisor, National Geophysical Co.), 5834 Belmont, Dallas, Tex.
Hohag, Walton H., Jr. (Senior Geophysicist, General Petroleum Corp.), 605 S. David St., Casper, Wyo.
Holbert, Murrell (Observer, Geophysical Service, Ind.), 1311 Republic Bank Bldg., Dallas, Tex.
Hole, H. W. (General Manager), c/o New Brunswick Gas & Oil Fields, Ltd., P. O. Box 194, Moncton, N. B., Canada.
Holekamp, O. G. (Seismologist, Shell Oil Co., Inc.), Drawer 5157, Drew Station, Lake Charles, La.
Hollingsworth, W. E. (Seis. Supervisor), c/o Sun Oil Co., Beaumont, Tex.
Hollingsworth, W. W. (General Manager, Magnetex Geophysical Co.), 604 Burk Burnett Bldg., Ft. Worth, Tex.
Hollis, Jack L. (Supervisor), c/o Seismograph Service Corp., Box 2463, Amarillo, Tex.
*Holmer, Ralph C. (Geological Observer), c/o California Co., 1818 Canal Bldg., New Orleans 12, La.
*Holser, William T. (Lecturer in Geology), Dept. of Geology, Columbia University, Morningside Heights, New York, N. Y.
Homan, W. L. (Seis. Party Chief, Petty Geophysical Co.), Box 2061, San Antonio, Tex.
Honnell, Pierre M. (Associate Professor), Dept. of Electrical Engineering, Washington University, St. Louis 5, Mo.
Hoover, Herbert, Jr. (President), United Geophysical Co., Rm. 107, 595 E. Colorado St., Pasadena, Calif.
Hoover, J. W. (Vice-President in Charge of Exploration, California Co.), 420 Darrington, New Orleans, La.
Hopkins, James S. (Party Chief, Amerada Pet. Corp.), Box 2040, Tulsa, Okla.
Horn, J. W. (Seis. Supervisor), c/o Garrett Exploration Co., 7015 Hillcrest Ave., Dallas, Tex.
Horton, Claude Wendell (Research Physicist & Asst. Professor), Defense Research Lab., University of Texas, Austin, Tex.
Horton, H. M. (Independent Geologist), Box 942, Eureka, Calif.
Horvitz, Leo (President, Horvitz Research Labs., Inc.), 3217 Milam St., Houston, Tex.
Houghton, H. M. (Geophysicist, Amerada Pet. Corp.), Box 2040, Tulsa, Okla.
House, A. Maxwell (Instrument Supervisor, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
*House, H. M. (Gravity Party Chief), c/o Socony-Vacuum de Colombia, Aptdo. Aereo 4034, Bogota, Colombia, S. A.
*Hovey, Ivan C. (Laboratory Technician, Radio Communications Lab.), 6206 Taggert St., Houston, Tex.
Howard, G. C. (Asst. Geophysical Supervisor, Union Producing Co.), Box 1407, Shreveport, La.
*Howe, Ralph H. (Geologist), c/o The California Co., 1818 Canal Bldg., New Orleans 12, La.
Howell, B. F., Jr. (Physicist, United Geophysical Co.), 1299 Wesley Ave., Pasadena 7, Calif.

Howell, Lynn G. (Geophysicist, Humble Oil & Refining Co.), 22 Courtland Place, Houston 6, Tex.
*Howell, T. M. (Civil and Mining Engr., Floridin Co.), P. O. Box 510, Quincy, Fla.
Howerton, Bert P. (Party Chief, Seismic Exploration Co.), Box 47, Corpus Christi, Tex.
Hoylman, H. Wayne (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Hubbard, Bela (Geologist, Standard Oil Co. of N. J.), 1405 E. Kleindale Rd., Tucson, Ariz.
Hubbard, Charles L. (Research Geophysicist, Humble Oil & Refining Co.), 203 Humble Bldg., Houston 2, Tex.
Hubbert, M. King (Assoc. Director of Exploration & Production Research, Shell Oil Co., Inc.), Box 2099, Houston, Tex.
Hubby, L. M. (Party Chief, Texas Co.), Box 2332, Houston, Tex.
Hudson, Joe B. (Geophysical Computer, Humble Oil & Refining Co.), 2316 American Bank Bldg., New Orleans, La.
Hughes, Darrell S. (Professor of Physics), Dept. of Physics, University of Texas, Austin, Tex.
Hughes, Roland F. (Development Engineer, Continental Oil Co.), 915 N. 3rd St., Ponca City, Okla.
Hughson, Barrett B. (Seismologist, Shell Oil Co.), Box 720, Casper, Wyo.
Hull, J. W. (Party Chief), c/o Apache Exploration Co., Box 1711, Houston, Tex.
Hunkapiller, B. B., c/o Shell Oil Co., Inc., Lake Charles, La.
Hunzicker, A. A. (Geophysical Supervisor, Texas Co.), Box 1720, Ft. Worth, Tex.
Hurd, Clinton O., c/o A. W. Hurd, Box 671, Arvada, Colo.
Hurry, Clare N. (Geophysical Operations Asst., Carter Oil Co.), Box 801, Tulsa, Okla.
Hutchinson, C. C. (Sales Engineer, Century Geophysical Corp.), 2208 E. 17th Pl., Tulsa 4, Okla.

Imle, Harry R. (Seis. Party Chief), c/o Carter Oil Co., Box 816, Craig, Colo.
Imle, John F. (Safety Supervisor), c/o Petty Geophysical Engineering Co., Box 2061, San Antonio, Tex.
*Ingle, G. W. (Party Chief, Oil Exploration, Inc.), Box 308, Palestine, Tex.
Innes, Arland I. (Geophysical Supervisor, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Irby, W. L. (Operator), c/o Tropical Oil Co., Apartado Aereo 3533, Bogota, Colombia, S. A.
Itria, Oswald (Supervisor), c/o Texas Petroleum Co., Postal 877, Bogota, Colombia, S. A.
Itten, Howard (Asst. Division Seis. Supervisor, Stanolind Oil & Gas Co.), Box 1410, Ft. Worth, Tex.
Ittner, Frank (Chief Seismologist, Pacific Div.), c/o Superior Oil Co., 930 Edison Bldg., Los Angeles, Calif.
Ivanhoe, L. F., Jr. (Geophysicist), c/o Venezuelan Atlantic Refining Co., Apartado 893, Caracas, Venezuela, S. A.
Ivy, John S. (Consulting Geophysicist & Petroleum Engineer), 1124 N. Esperson Bldg., Houston 2, Tex.

*Jackson, C. Kenneth (Chief Computer, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Jackson, G. L. (Engineer, Humble Oil & Refining Co.), Box 253, Livingston, Tex.
*Jackson, James G., Jr. (Chief Computer), c/o Western Geophysical Co., Party 8, 3530 N. Chester Ave., Bakersfield, Calif.
Jackson, O. B. (Seismologist), c/o Shell Oil Co., Inc., Box 2061, Odessa, Tex.
Jackson, Ralph S. (Vice-President, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Jackson, Robert W. (Lt. Col., U. S. Army Signal Corps.), Post Signal Officer, Fort Sill, Okla.
*Jacobsen, Peter, Jr. (Geophysicist), c/o Creole Petroleum Corp., Apartado 889 Caracas, Venezuela, S. A.

Jakosky, J. J. (Consulting Engineer), 1063 Gayley Ave., Los Angeles 24, Calif.
*Jansen, M., J. J. H., 83 So. St., Morristown, N. J.
Jasper, Walter E. (Asst. Seismologist, Shell Oil Co., Inc.), Box 1509, Midland, Tex.
Jeffers, Paul H. (Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Jennings, Bruce M., Jr. (Gravity Party Chief, Magnolia Petroleum Co.), Box 900, Dallas, Tex.
Jennings, D. Mitchell (Chief Engineer and Geophysicist, Scientific Exp. Service), Box X, Newell, S. Dak.
Jensen, Homer, (Chief, Magnetometer Div.), c/o Aero Service Corp., 236 E. Courtland St., Philadelphia 20, Pa.
Jett, J. E. (Costal Supervisor, Geotechnical Corp.), 408 Sue St., Houston, Tex.
Joesting, Henry R. (Chief, Section of Geophysics), U. S. Geological Survey, Washington 25, D. C.
†Johnson, Albert E. (Geophysicist, McIntyre Porcupine Mines, Ltd.), P. O. Box 618, Schumacher, Ontario, Canada.
Johnson, Byron K. (Party Chief, Atlantic Refining Co.), P. O. Box 189, Houma, La.
Johnson, Curtis H. (Geophysicist, General Petroleum Corp.), 3670 Melville Dr., San Marino 9, Calif.
*Johnson, E. W. (Seis. Party Manager), Geophysics Dept., Cities Service Oil Co., Bartlesville, Okla.
Johnson, F. L. (Asst. Director, Sun Physical Research & Development Lab.), 201 Rodney Road, Ridley Park, Pa.
Johnson, Frank B. (Research Geophysicist, Humble Oil & Refining Co.), 205 Humble Bldg., Houston 1, Tex.
Johnson, G. R. (Owner, Radar Exploration Co.), Box 308, Toronto, Ontario, Canada.
Johnson, James F. (Geophysicist, Sinclair Prairie Oil Co.), 624 Westwood, Ft. Worth, Tex.
*Johnson, Joseph C. (Computer, Seis. Party), c/o Carter Oil Co., Box 272, Warren, Ark.
Johnston, Frank M., Box 487, Rawlins, Wyo.
Jones, Harold H., 5233 Mission Woods Rd., Kansas City 3, Kan.
*Jones, Huston T., Jr. (Computer, Stanolind Oil & Gas Co.), 2511 E. 2nd St., Tulsa, Okla.
*Jones, J. Byron, 319 Walton St., LeMoyne, Pa.
*Jones, John P. (Geophysicist, Western Geophysical Co.), c/o Stanolind Geoph. Lab., Box 591, Tulsa, Okla.
Jones, Leland W. (Geologist, Anderson Prichard Oil Corp.), 1000 Apco Tower, Oklahoma City, Okla.
Jones, M. P. (Vice-President, Garrett Exploration Co.), 7015 Hillcrest, Dallas, Tex.
Jones, R. W. (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Jones, Varnakale L. (Consulting Geophysicist & Head of Dept. of Geophysics, U. of Tulsa), 1321 So. Carson, Tulsa, Okla.
Jonsson, J. E. (Vice-President & Treasurer, Geophysical Service, Inc.), 4305 Bellaire, Dallas, Tex.
Jordon, C. K. (Development Engineer), c/o Continental Oil Co., Ponca City, Okla.
Jubran, Joseph (Chief Computer, Rogers-Ray, Inc.), c/o Socony-Vacuum Oil Co., 62 Ibrahim Pasha St., Cairo, Egypt.
Judson, Sidney A. (Geologist, Texas Gulf Producing Co.), 3783 Carlton St., Houston 5, Tex.
Junger, Arne (Seismologist, Shell Oil Co., Inc.), 809 Fourth St. W., Calgary, Alberta, Canada.

Kaiser, George B. (Lt. Col., Asst. Chief of Air Staff, A-6, Hq. 14th Air Force), Box 574, Wharton, Tex.
Kamen-Kaye, M. (Chief Geologist), c/o Caracas Petroleum Corp., Aptdo. 89, Caracas, Venezuela, S. A.
Kamitchis, James E. (Graduate Asst., University of Okla.), Box 532, Route 8, Oklahoma City, Okla.

Kannenstine, Fabian M. (Owner, Kannenstine Labs.), P. O. Box 6007, Houston 6, Tex.
Karcher, J. C. (Independent), 406 Continental Bldg., Dallas 1, Tex.
Kaufman, G. F. (Geophysical Research Co-ordinator), c/o Standard-Vacuum Oil Co., 26 Broadway, New York 4, N. Y.
Keen, C. D. (Head Physics & Engineering Dept., Centenary College), 529 Robinson Place, Shreveport 21, La.
*Kelley, Clovis C. (Computer, Independent Exploration Co.), Box 613, Olustee, Okla.
Kelley, Sherwin F. (President, Geophysical Explorations, Ltd.), P. O. Box 23, Amawalk, N. Y.
Kelley, W. W. (Independent Operator), 199 Wyckham Rise, San Antonio 2, Tex.
*Kelsch, Raymond L. (Surveyor & Permit Man, Superior Oil Co.), Box 1457, Levelland, Tex.
Kelsey, Martin C. (President, Rayflex Exploration Co.), 3312 Caruth Blvd., Dallas 5, Tex.
Kempsky, Philip J. (Party Chief, Amerada Petroleum Corp.), 552 Subway Terminal Bldg., Los Angeles 13, Calif.
Kendall, G. D. (Geophysical Supervisor, Deep Rock Oil Corp.), Box 1051, Tulsa, Okla.
Kendall, James M. (Physicist, Naval Ordnance Lab.), 5309 Pard Rd. (Md.), Washington 19, D. C.
*Kendall, J. M. (Seismic Computer, Texas Company), Box 77, Virginia, Minn.
Kendall, W. B. (Party Chief, Gulf Research & Development Co.), Box 2040, Tulsa, Okla.
Kennedy, Edward P. (Party Chief, Geotechnical Corp.), 3454 Normandy Ave., Dallas, Tex.
Kennedy, Frank H. (Chief Engineer, Geotechnical Corp.), P. O. Box 7166, Dallas 9, Tex.
Kerbow, R. B. (Seis. Party Mgr., Gulf Research & Development Co.), P. O. Drawer 2038, Pittsburgh 30, Pa.
*Kern, Jack C. (Geologist, Standard Oil Co. of Tex.), 3815 Greenbrier Drive, Dallas, Tex.
Kerr, V. Robert (Seismologist, Cummins, Berger & Pishney), 1603 Commercial Standard Bldg., Ft. Worth 2, Tex.
Kezeler, J. L. (President, Key Velocities, Inc.), Box 1824, Tulsa, Okla.
Kidd, Robert L. (Manager Land & Geological Div.), c/o Cities Service Oil Co., Bartlesville, Okla.
Kidder, Harold J. (Seismic Supervisor), c/o Socony-Vacuum Oil Co., Apartado Aereo 4034, Bogota, Colombia, S. A.
Kiesler, Ernest A. (Party Chief, Geophysical Service, Inc.), 6000 Lemmon Ave., Dallas 9, Tex.
*Kilborn, J. M. (Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh, Pa.
Kipfer, H. L. (Designer, Black & Veatch), 119 East 85th St., Kansas City 5, Mo.
Kittredge, F. R. Party Chief, Petty Geophysical Engineering Co.), 1205 Hunt Bldg., Tulsa, Okla.
*Klabzuba, Robert E. (Junior Computer, Atlantic Refining Co.), Prague, Okla.
Klaus, H. (President, Klaus Exploration Co.), Box 1617, Lubbock, Tex.
Klein-Haneveld, A (Geophysicist), c/o Cia de Petroleo, Shell de Colombia, Apartado 3439, Bogota, Colombia, S. A.
Koenig, Palmer E. (Asst. Radio Engineer, Aircraft Radio Lab.), 4302 N. Main, Dayton, Ohio.
Koeppel, B. W. (Observer), c/o Seismograph Service Corp of Dela., Aptdo, 1488, Caracas, Venezuela, S. A.
Kogbetliantz, Ervand (Professor of Mathematics, French University), 438 W. 116th St., Apt. 56, New York 27, N Y.
Kohler, A (Seismologist, Petty Geophysical Engineering Co.), Box 2061, San Antonio, Tex.
Kohler, G. J., Jr. (Party Chief, Geophysical Service Corp.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Konkel, Philip M. (Geologist), c/o Ohio Oil Co., Oil & Gas Bldg., Houston 2, Tex.

Konz, Leo W. (Seis. Computer, Sun Oil Co.), 1502 Central Drive, Beaumont, Tex.
Koulomzine, Th. (Sr. Partner, Koulomzine, Geoffroy, Mossard & Co.), Box 870, Val D'or, Quebec, Canada.
Krause, Fred W. (Party Chief, Yegua Corp.), 2302 Experson Bldg., Houston 2, Tex.
*Kretz, Robert L. (Geologist, California Co.), 1006 U. S. Nat'l Bank Bldg., Denver 2, Colo.
*Kundert, Karl H. (Geophysicist, Barnsdall Oil Co.), Box 2039, Tulsa, Okla.
Kunkel, T. L. (Party Chief, Texas Co.), Box 112, Liberal, Kans.

Ladner, A. L. (Partner, Apache Exploration Co.), P. O. Box 1711, Houston, Tex.
Lamb, George B. (Asst. Chief Geophysicist, Gulf Oil Corp.), P. O. Box 2100, Houston 1, Tex.
Lamb, William C. (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh, Pa.
Lambert, G. D. (Geophysicist, Shell Oil Co.), 3156 S. Madison, Tulsa, Okla.
Lamkin, Woodrow W. (Asst. Gravity Meter Supervisor, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.
Lamon, Robert S. (Dist. Geologist), c/o Richmond Exploration Co., Apartado 93, Maracaibo, Venezuela, S. A.
Lang, Harold M. (Geophysical Instrument Construction Supervisor, Stanolind Oil & Gas Co.), 5303 E. 7th St., Tulsa, Okla.
Lang, Ralph H. (Geophysicist, Gulf Res. & Development Co.), Box 1290, Ft. Worth, Tex.
Larson, Carl L., Jr. (Div. Mgr. of Exploration, Stanolind Oil & Gas Co.), Box 40, Casper, Wyo.
LaRue, James E. (Asst. Chief of Geophysics), c/o Humble Oil & Refining Co., Houston, Tex.
LaRue, Wilton W. (Chief Geophysicist), c/o Plymouth Oil Co., Sinton, Tex.
Lash, Charles C. (Research Engineer, Stanolind Oil & Gas Co.), 1111 E. 25th St., Tulsa, Okla.
*Latimer, M. W. (Manager, Hercules Powder Co.), 506 Joplin Nat'l Bank Bldg., Joplin, Mo.
Lawhorn, O. T. (Geophysicist, Pan American Production Co.), 1248 Mellie Esperson Bldg., Houston 2, Tex.
Lawrence, K. M. (Seis. Party Chief), c/o Geophysical Research Corp., Box 2040, Tulsa 2, Okla.
Laws, Junius O. (Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Lay, Roy L. (Asst. Manager, Geophysical Div., Texas Co.), Box 2332, Houston 1, Tex.
Lea, N. J. (Seis. Party Chief, Texas Co.), 307 N. Columbus, Marshall, Tex.
Lea, W. T. (Seis. Party Chief, Arkansas Fuel Co.), 239 Rutherford St., Shreveport, 52, La.
Le Conte, Joseph (Geologist, Richfield Oil Co.), 560 Haberfelde Bldg., Bakersfield, Calif.
Ledyard, Paul H. (Vice-President, Southern Geophysical Co.), 1004 Sinclair Bldg., Ft. Worth 2, Tex.
Lee, Walter B., Jr. (Geophysical Supervisor, Gulf Research & Development Co.), Box 562, Liberty, Tex.
Leedy, F. B. (Vice-President & Manager of Colombian Div., Seismograph Service, Corp.), Box 1590, Tulsa, Okla.
Leet, L. Don (Director, Harvard Seismograph Station, Harvard University), R. F. D., Harvard, Mass.
Legge, J. A., Jr. (Geophysical Supervisor, United Geophysical Co.), Box 1310, Fairbanks, Alaska.
Legrand, J. C. (Vice-President, Schlumberger Well Surveying Corp.), 5319 Mandell St., Houston 5, Tex.
Leonardon, E. G. (President, Schlumberger Well Surveying Corp.), Box 2175, Houston 1, Tex.
Lester, John A. (Field Seismis Supervisor, Magnolia Petroleum Co.), Box 900, Dallas, Tex.

Lester, O. C., Jr. (Supervisor of Geophysics), c/o Amerada Petroleum Corp., 552 Subway Terminal Bldg., 417 Hill St., Los Angeles 13, Calif.
*Leverich, William P., W. E. Brogan Co., 2711 Crocker, Houston 6, Tex.
Levings, W. S. (Instructor), Dept. of Geology, Colorado School of Mines, Golden, Colo.
Lewis, Wm. Bradley (Vice-President), The Elflex Co., 1706 Esperson Bldg., Houston 2, Tex.
*Lindsey, E. B. (Party Chief, Seismograph Service Corp.), 1040 Boulevard, Shreveport, La.
Linehan, Daniel, S.J. (Seismologist in Charge), Weston College, Weston 93, Mass.
Linwell, Martin V. (Party Chief, Geophysical Service, Inc.), Caixa Postal 820, Belem, Para, Brazil, S. A.
Lipson, Edward (Consulting Engineer), 3450 Gunston Rd., Alexandria, Va.
Livingston, E. C. (Party Chief), c/o Atlantic Refining Co., Geophysical Section, Box 2819, Dallas 1, Tex.
Locke, Edgar R. (Supervisor, Texas Co.), 2214 Swift Blvd., Houston 5, Tex.
Lockwood, R. P. (Zone Geologist, Gulf Oil Corp.), 507 Lancaster Bldg., Calgary, Alta., Canada.
Lohse, John M. (Research Engineer, Consolidated Vultee Aircraft Corp.), 128 Jewel St., Longview, Tex.
Lomax, C. J. (Party Chief, Atlantic Refining Co.), Kremmling, Colo.
Long, C. J. (Party Chief, Stanolind Oil & Gas Co.), Box 332, Chickasha, Okla.
Long, James A. (Party Chief), United Geophysical Co., Apartado 93, Maracaibo, Venezuela, S. A.
Long, John V. (Research Physicist, Solar Aircraft Co.), 4120 5th Ave., San Diego 3, Calif.
Longley, W. Warren (Professor of Geology), Dept. of Geology, University of Colorado, Boulder, Colo.
*Loring, Ralph C. (Asst. Seismologist, Shell Oil Co., Inc.), Drawer 5157, Drew Station, Lake Charles, La.
Lovejoy, Joe Bernard (Geologist, Gulf Oil Corp.), P. O. Box 1290, Ft. Worth, Tex.
Low, R. M., Apartado Aereo 4000, Bogota, Colombia, S. A.
Lowe, C. R. (Supervisor, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Ludwick, C. C. (Seismologist, Shell Oil Co., Inc.), Box 1191, Tulsa, Okla.
Lukens, John P. (President, Oklahoma Seismograph Co.), Box 579, Shawnee, Okla.
Lundberg, Hans (President, Hans Lundberg, Ltd.), 80 Richmond St., W., Toronto, Ontario, Canada.
Lynch, J. Joseph, S.J. (Director Seismic Observatory), Fordham University, New York, N. Y.
*Lynch, Jack (Surveyor, Independent Exploration Co.), c/o Texas Petroleum Co., Barranquilla, Colombia, S. A.
Lynn, Ralph D. (Research Physicist, Carter Oil Co.), 1603 E. 35th St., Tulsa 5, Okla.
Lynton, Edward D. (Oil Consultant, Instut du Petrole), c/o Mrs. T. J. Potter, 702 N. Central Ave., Glendale 3, Calif.
Lyons, Paul L. (Technical Supervisor, Carter Oil Co.), Box 801, Tulsa, Okla.

*Mace, H. G. (Seismologist, United Geophysical Co.), Box 546, Chickasha, Okla.
Macelwane, James B., S.J. (Dean Institute of Geophysical Technology, St. Louis University), 3621 Olive St., St. Louis 8, Mo.
MacMahan, Andrew M. (Consulting Physicist), 2501 Southmore Blvd., Houston, Tex.
†MacNeill, Walter J. (Student, University of Toronto), 20 Queen Anne Road, Toronto 9, Ontario, Canada.
MacNaughton, Lewis W. (Partner, DeGolyer & MacMaughton), 1000 Continental Bldg., Dallas, Tex.
*MacSween, G. B. (Research Asst., Geotechnical Corp.), 7 Wolseley Ave., St. Catharines, Ontario, Canada.
Malamphy, Mark C. (Sr. Technologist, U. S. Bureau of Mines), P. O. Box 108, Springbok, Namaqualand, Union of South Africa.
Maliphant, H. C. (Seismologist), c/o Caribbean Petroleum Co., Caracas, Venezuela, S. A.

Manes, O. B. (Area Seismologist, Shell Oil Co., Inc.), 3742 Sunset Blvd., Houston 5, Tex.
Manhart, T. A. (Executive Vice-President, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Mann, Neil W. (Supervisor & Brazil Representative, Geophysical Service, Inc.), Cx. Postal No. 820, Belem, Para, Brazil, S. A.
*Manning, A. B. (Capt. U. S. Army), 1138 Albion, Denver 7, Colo.
Mansfield, Robert H (Seismologist), c/o United Geophysical Co., Apartado 1085, Caracas, Venezuela, S. A.
*Marble, Kennedy R. (Gravity Party Chief, Tropical Oil Co.), 4308 Chase St., Denver, Colo.
Maree, Burgert D. (Geophysicist, Geological Survey), Box 401, Pretoria, Union of South Africa.
Marquardt, Carlton M. (Geophysicist, Combined Metals Reduction Co.), Box 178, Salt Lake City 8, Utah.
Marr, Jno. D. (Executive Supervisor, Seismic Explorations, Inc.), 1722 Rice Blvd., Houston, Tex.
Marsh, Samuel R. (Seis. Party Chief, Carter Oil Co.), Aptdo 1329, Caracas, Venezuela, S. A.
Marshall, H. D. (Party Chief, Western Geophysical Co.), Box 596, Natchez, Miss.
Marston, John (Party Chief, Seismograph Service Corp.), Apartado 1488, Caracas, Venezuela, S. A.
Martens, Willis P. (Party Chief, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Martin, Dick (District Manager, Illinois Powder Mfg. Co.), R. 3, Box 257, Tulsa 15, Okla.
Martin, Jack (Seis. Party Chief, General Geophysical Co.), 2514 Gulf Bldg., Houston 2, Tex.
Martin, James Milton (Seismic Computer, Magnolia Petroleum Co.), Box 961, Roswell, New Mex.
Martin, Rodolfo (Seismic Party Chief, Argentine Gov't. Oil Fields), Avda. Roque Saenz Pena 777, Buenos Aires, Argentina, S. A.
Martin, Sidney A., Jr. (Research Geophysicist, Humble Oil & Refining Co.), Box 2180, Houston 1, Tex.
*Martin, W. Obier (Student, Louisiana State University), Box 5441, University Station, Baton Rouge, La.
Martyn, Phil F. (Petroleum Geologist), 2020 Albans Rd., Houston 5, Tex.
Mathews, John W. (Geophysicist, Richfield Oil Corp.), 560 Haberfelde Bldg., Bakersfield, Calif.
Matjasic, Wallace L. (Geologist, Honolulu Oil Corp.), 410 Professional Bldg., Bakersfield, Calif.
Matthews, W. A. (Asst. Div. Seismograph Supervisor, Stanolind Oil & Gas Co.), 1335 W. Gray, Houston, Tex.
Maxey, J. R. (Supervisor), c/o United Geophysical Co., Aptdo. 1085, Caracas, Venezuela, S. A.
Maxwell, E. (Staff Member of Radio Lab., Massachusetts Inst. of Tech.), 161 Cypress St., Brookline, Mass.
Mayes, Tom D. (Partner, Mayes-Bevan, Inc.), 305 Kennedy Bldg., Tulsa 3, Okla.
Mayfield, William I. (Geologist), c/o Continental Oil Co., Box 1800, Wichita Falls, Tex.
McAlister, C. H. (Chief Geophysicist, Sunray Oil Corp.), 11th Floor, Philtower, Bldg., Tulsa, Okla.
McBurney, Charles G. (Partner, Seismic Engineering Co.), 5102 W. Hanover, Dallas 9, Tex.
McCain, Hugh, Jr. (Computer), c/o Nance Exploration Co., P. O. Box 774, Hattiesburg, Miss.
McCaleb, M. M. (Gravity Meter Supervisor, Humble Oil & Refinining Co.), P. O. Box 854, Tallahassee, Fla.
McCann, K. G. (Chief Geophysicist, Superior Oil Co.), 234 Oil & Gas Bldg., Houston 2, Tex.
McCarver, Holland C. (Chief Geophysicist, Seaboard Oil Co.), 1400 Continental Bldg., Dallas 1, Tex.

McClosky, Downs (Geologist), c/o Amerada Petroleum Corp., 417 S. Hill St., Los Angeles, Calif.
McClure, C. E. (Supervisor, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
McCollum, Burton (President McCollum Exploration Co.), 853 Esperson Bldg., Houston 2, Tex.
McCollum, Elton V. (Partner, E. V. McCollum & Co.), 1510 Thompson Bldg., Tulsa 3 Okla.
*McCormack, Harold R. (Computer, Sun Oil Co.), 2290 North St., Beaumont, Tex.
McCracken, Guy I. (Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
McCready, H. J., Jr. (Geophysicist, E. V. McCollum Co.), Box 244, Sapulpa, Okla.
*McCullagh, John, Jr., 2110 South Blvd., Houston 6, Tex.
McDaniel, C. M., Jr. (Party Chief, Atlantic Refining Co.), Box 240, Arkansas City, Kans.
McDermott, Eugene (President, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dalias 1, Tex.
*McDonald, William C. (Field Seismologist, United Geophysical Co.), Party 14, Box 67, Anaheim, Calif.
McDonald, H. W. (Party Chief, Keystone Exploration Co.), 3829 Gertin St., Houston, Tex.
McDougall, John E. (Geophysicist, Atlantic Refining Co.), 37 Eucalyptus Street, Maplewood, La.
McGann, Robert J., (address unknown).
McGee, John E. (Geophysical Supervisor, Gulf Research & Development Co.), Box 2100, Houston 1, Tex.
McGhee, George C. (Spec. Asst. to Under-Secretary of State for Econ. Affairs, Dept. of State), 2406 Kalaroma Rd., Washington 8, D. C.
McGrady, Dupree (Seis. Crew Supervisor, Western Geophysical Co.), P. O. Box 693, Casper, Wyo.
McGuckin, Glenn M. (Owner, Reliable Geophysical Co.), Box 1111, Corpus Christi, Tex.
McKay, A. E. (Asst. Head Geophysics Section), c/o Atlantic Refining Co., P. O. Box 2819, Dallas, Tex.
McKee, James B. (Asst. Seismologist, Shell Co., Inc.), Box 789, Shreveport, La.
McKinsey, M. H. (Seismograph Supervisor, Shell Oil Co., Inc., Box 1509, Midland, Tex.
*McLay, Harold (Geophysical Co-ordinator, Atlantic Refining Co.), Apartado 893, Caracas, Venezuela, S. A.
McLemore, Ethel Ward, Rt. 1, Box 104C, Aledo, Tex.
McLoad, Kenneth W. (Engineer, Geophysical Lab., Magnolia Petroleum Co.), 4026 Parkside Drive, Dallas 9, Tex.
McManus, Jack V. (Field Engineer, Geophysical Service, Inc.), 524 W. Hillsboro St., El Dorado, Ark.
McMillen, R. E. (Geophysical Supervisor), c/o Phillips Venezuelan Oil Co., Apartado 1031, Caracas, Venezuela, S. A.
McMullin, Elbert F. (Party Chief, Rayflex Exploration Co.), 2321 NE. 24th St., Oklahoma City, Okla.
McMurray, Howard (Geophysical Investigator), New Jersey Zinc Co., Research Div., Palmerton, Pa.
*McNally, P. M. (Party Chief), c/o Phillips Petroleum Co., Crew #3, Anadarko, Okla.
McNatt, E. M. (Head of Geophysical Research, Carter Oil Co.), 1721 E. 37th St., Tulsa, Okla.
McReynolds, Gregg F., 3106 Plumb St., Houston 5, Tex.
*Meade, George N. (Computer, Magnolia Petroleum Co.), Box 411, Sulphur, Okla.
*Meador, Bernal M. (Radio Engineer, Transcontinental & Western Air Lines), 604 W. 86th Terrace, Kansas City 5, Mo.
*Mehringer, A. P. (Chief Computer, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
*Mehta, Abdul K. (Geologist, the Punjab Government, India), "Hermitage" Moore Ave., Tollygunge, Calcutta, India.

Meitzen, J. B. (Geophysics Supervisor, Humble Oil & Refining Co.), 2316 American Bank Bldg., New Orleans 12, La.
Melton, Ben S. (Staff Member, Applied Physics Lab., Johns Hopkins University), 8708 Geren Road, Silver Spring, Md.
Menefee, J. C. (Asst. Director Geophysical Exploration, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Mercier, Vincent J. (Division Engineer, Lane-Wells Co.), 802 Central Building, Wichita, Kans.
Merritt, W. C. (Geophysicist), c/o Creole Petroleum Co., Exploration Dept., Aptdo. 889, Caracas, Venezuela, S. A.
Meszaros, W. A. (Party Manager, Gulf Research & Development Co.), Drawer 2038 Pittsburgh 30, Pa.
Metzner, Loyde H. (Asst. Chief Geologist), c/o Signal Oil & Gas Co., 811 W. 7th St., Rm. 1116, Los Angeles, Calif.
*Migaux, Leon (General Manager), c/o Cie Generale de Geophysique, 48 Blvd. de La Tour Maubourg, Paris, France.
Miller, E. L., Jr. (Asst. Prof. of Geological Engineering, North Carolina State College), Box 5606, Raleigh, N. C.
Miller, Nash H. (Field Engineer, United Geophysical Co.), 2157 Orange St., Abilene, Tex.
Miller, R. D. (Geophysicst), c/o Shell Oil Co., Inc., Box 2099, Houston, Tex.
Miller, Vincent (President, Exploration Service Co.), Box 1289, Bartlesville, Okla.
Millet, M. J. (Party Chief, Texas Co.), Box 2332, Houston, Tex.
Millington, John W. (Research Engineer, Sun Oil Co.), 2237 Calder Ave., Beaumont, Tex.
*Mills, Frank (Chief Computer, National Geophysical Co.), Box 1377, Vernon, Tex.
Mims, R. Lewis (Graduate Student, University of Texas), 1817 E. 4th St., Austin, Tex.
Milstein, Mark N. (Consulting Geophysicist), 489 Fifth Ave., New York, N. Y.
Minton, J. P. (Research Adviser, Magnolia Petroleum Co.), 501 Argyle Apt., Hall & Oaklawn, Dallas 4, Tex.
‡Mintrop, L., 22 a Essen-Werden Barkhovenalle 36 (British Zone), Germany
*Mitcham, F. M., Jr. (Party Chief, Oil Exploration, Inc.), 604 McBirney Bldg., Tulsa, Okla.
Mitchell, Fielding L. (Lt., U.S.N.R.), 719 So. Royal St., Alexandria, Va.
Mitchell, George D., Jr. (President, Advanced Exploration Co.), 622 First National Bank Bldg., Houston 2, Tex.
Mitchell, W. R. (Vice-President in Charge of Services, National Geophysical Co.), 8806 Lemmon Ave., Dallas, Tex
Mix, Adrian E. (Geologist, Socony-Vacuum Oil Co.), Apartado 246, Caracas, Venezuela, S. A.
Mollere, John C. (Observer, Western Geophysical Co.), 1333 S. Hope St., Los Angeles 15, Calif.
Montgomery, George P., Jr. (Seismic Party Chief, Humble Oil & Refining Co.), 3779 Elmora St., Houston 5, Tex.
Moody, Herbert H. (Observer), c/o Rayflex Exploration Co., 6923 Snider Plaza, Dallas 5, Tex.
Moody, N. K., Jr. (Party Chief, Seismograph Service Corp.), Box 2463, Amarillo, Tex.
Moore, Arthur A., Jr. (Div. Supervisor, Geophysics, Humble Oil & Refining Co.), 711 San Angelo National Bank Bldg., San Angelo, Tex.
Moore, Charles M., Jr. (Party Chief, Geophysical Service, Inc.), 4411 Glenwood, Dallas, Tex.
Moore, F. A. (Computer, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Moore, Homer C. (President Oil Exploration, Inc.), 604 McBirney Bld., Tulsa, Okla.
*Moore, Horace Strong (Draftsman, Project Engineer, Southwestern Engineering Co.), 2204 Floral Drive, Whittier, Calif.
Moore, J. Hiram (District Geologist, Fullerton Oil Co.), Box H, Hobbs, New Mex.

Moore, James A. (Chief Geologist), c/o Union Sulphur Co., Sulphur, La.
Moore, Robert Roy (Computer, Geophysical Service, Inc.), Norte 4, #15, Orizala, Ver., Mexico.
Moore, W. L., Jr. (District Supervisor, Petty Geophysical Engineering Co.), 1205 Hunt Bldg., Tulsa 3, Okla.
Moorman, H. R. (Chief Geophysicist, Socony-Vacuum Oil Co.), Apartado 246, Caracas, Venezuela, S. A.
*Moose, Dale H. (Chief Seismologist, North American Geophysical Co.), 2627 Westheimer Rd., Houston 6, Tex.
Moran, R. B., Jr. (Electronic Engineer, USN Research Lab.), 3328 Marth Circle, Pasadena 8, Calif.
*Moran, Ray O. (Senior Computer, Atlantic Refining Co.), Geophysical Section, Box 2819, Dallas, Tex.
Morehead, Jack N. (Party Chief), c/o Southern Geophysical Co., 1003 Sinclair Bldg., Ft. Worth, Tex.
Morgan, Chas. Gill, 287 Waltham St., West Newton, Mass.
Morgan, Wesley H. (Geophysicist), c/o Standard Oil Co. of Cuba, Apartado 1303, Havana, Cuba.
†Morley, L. W. (Student, University of Toronto), 494 9th St. E., Owen Sound, Ontario, Canada.
Morris, James L. (Geologist, Pure Oil Co.), Box 2107, Ft. Worth, Tex.
Morris, Lawrence K. (Geophysical Supervisor), c/o United Geophysical Co., 595 E. Colorado St., Pasadena 1, Calif.
Morrison, M. S. (Partner, C. C. Smith Drilling Co.), 3411 21st St., Lubbock, Tex.
*Morrison, W. D. (Observer, Independent Exploration Co.), Box 389, Houma, La.
Mossman, R. W. (Party Supervisor, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Mott-Smith, L. M. (Physicist), 1012 Shadder Way, Houston, Tex.
Mounce, W. D. (Research Associate, Humble Oil & Refining Co.), 256 Humble Bldg., Houston, Tex.
Mount, E. L. (Party Chief), Geophysical Division, Continental Oil Co., Ponca City, Okla.
Mower, L. K. (Area Geophysicist, Shell Oil Co., Inc.), 5311 Institute Lane, Houston, Tex.
Muffly, Gary (Development Engineer, Gulf Research & Development Co.), R. D. 1, Verona, Pa.
Murray, Matthew T. (Party Chief, Geophysical Exploration Co.), 503 Union Nat. Bank Bldg., Denver 9, Colo.
†Musgrave, Albert W. (Geophysical Assistant, Magnolia Petroleum Co.), Box 395, Madisonville, Tex.
Muskat, Morris (Chief of Physics Div., Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Muzzey, David S., Jr. (Chief Mine Division, Naval Ordnance Lab.), 3117 35th St., N. W., Washington 16, D. C.
Myers, Charles E., Box 492, Rosenberg, Tex.
Myers, John R. (Geophysicist, National Geophysical Co.), 8806 Lemmon Ave., Dallas, Tex.
Myers, Wm. Howard (Party Chief, United Geophysical Co.), 595 E. Colorado St., Pasadena 1, Calif.

Nahas, J. N. (Lt. Col., Faculty of Command and Staff College), 624 McClellan Ave., Fort Leavenworth, Kans.
Nalley, Leonard L. (Research Engineer, Western Geophysical Co.), 257 N. Kenmore, Los Angeles 4, Calif.
Narvarte, P. E. (Consulting Geophysicist), 307 Insurance Bldg., San Antonio, Tex.
Nash, C. C., Jr. (Capt., U. S. Signal Corps), 53 E. Middle St., Fairfield, Ohio.
Nash, John M. (Geophysicist, Gravity Interpretation, Shell Oil Co.), 2228 South Florence Ave., Tulsa, Okla.
Nash, Paul E. (Director, Geophysical Exploration, Magnolia Petroleum Co.), Box 900, Dallas, Tex.

Neese, U. E. (Chief Computer, North American Geophysical Co.), Box 707, Rosenberg, Tex.
Neff, W. D. (Geophysicist), c/o L. J. Neuman Co., 943 Mellie Esperson Bldg., Houston 2, Tex.
Nettleton, Lewis L. (Partner, Gravity Meter Exploration Co.), 1348 Esperson Bldg., Houston 2, Tex.
Neufeld, J. (Engineer), c/o Engineering Labs., Inc., 620 E. Fourth St., Tulsa, Okla.
Neuman, L. J. (President, L. J. Neuman Co.), 943 Mellie Esperson Bldg., Houston 2, Tex.
Newby, C. J. (Geophysicist, Humble Oil & Refining Co.), 855 Humble Bldg., Houston, Tex.
Newton, W. W. (Vice-President, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
Nichols, E. Turnley (District Geologist, California Co.), 1818 Canal Bldg., New Orleans, La.
Nisle, Robert G. (Graduate Fellow in Physics), Michigan State College, East Lansing, Mich.
*Noble, Francis H. (Seis. Recorder, Texas Co.), Route 1, Cooper, Tex.
*Normand, S. R. (Computer, Independent Exploration Co.), 1411 Electric Bldg., Ft. Worth, Tex.
*Norris, C. G. (Party Chief, Brown Geophysical Co.), Box 6005, Houston 6, Tex.
Northcutt, W. C., P. O. Box 1002, Estes Park, Colo.
Northrop, Joseph Walter, III (Geol. Observer, The California Co.), 1818 Canal Bldg., New Orleans 12, La.
Notley, W. E. (Asst. Grav. Meter Supervisor, Stanolind Oil & Gas Co.), Box 2089, Amarillo, Tex.
Novelly, W. O. (U. S. Army), Route 1, House Springs, Mo.
Nugent, R. M. (Party Chief, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Nutt, Willard, Thomas (Asst. Computer, Humble Oil & Refining Co.), Room 202 Humble Bldg., Houston, Tex.

O'Boyle, Charles C. (Graduate Student, Colorado School of Mines), Box 388, Golden, Colo.
Oddone, Decio S. (Asst. Engineer, Conselho Nacional de Petroleo), Rua Santa Amelia 35, (Matoso) Rio de Janeiro, Brazil, S. A.
Oden, A. J. (Seis. Party Chief, Magnolia Petroleum Co), Geophysical Laboratory, Box 900, Dallas 1, Tex.
Odenweller, Keith H. (Asst. Manager, Seismograph Service Corp.), Apartado 1488, Caracas, Venezuela, S. A.
O'Donnell, T. J. (Geophysicist, Gulf Research & Development Co.), 218 N. Craig St., Pittsburgh, Pa.
Officer, Helen V. (Laboratory Assistant, Carter Oil Co.), 1330 E. 26th St., Tulsa 5, Okla.
Olson, W. S. (Supervising Geologist, Texas Co), Room 2900, 135 E. 42nd St., New York 17, N. Y.
*Oliphant, Charles W. (President, Oliphant Labs., Inc.), 15 Brattle Circle, Cambridge 38, Mass.
Olson, Odell C. (District Engineer), c/o Oil & Gas Division, R. R. Commission of Texas, Abilene, Tex.
Olson, Robert W. (Chief Engineer, Geophysical Service, Inc.), 323 Circle Drive, Dallas, Tex.
Osterhoudt, Walter J. (Supervisor, Geophysical Operations, Houston Div., Gulf Res. & Dev. Co.), Drawer 2100, Houston 1, Tex.
Oudt, F. W. (Exploration Manager, Shell Oil Co., Inc.), Box 2099, Houston, Tex.
Owen, H. J. (Seis. Party Chief), Geological Dept., Phillips Petroleum Co., Bartlesville, Okla.
*Owings, B. F., Jr. (Party Chief, Garrett Exploration Co.), Box 267, Jacksboro, Tex.

*Paddison, Louis J. (Senior Research Engineer, Project Supervisor), c/o Res. & Dev. Division, New Mexico School of Mines, Albuquerque, N. M.

Page, C. Newton (Party Chief), c/o Seismograph Service Corp., Box 1590, Tulsa, Okla.
*Pakiser, Louis C., Jr. (Geophysical Computer), c/o Carter Oil Co., Geophysical Dept., Tulsa, Okla.
Palmer, Elton M. (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Palmer, John E. (Jr. Research Geophysicist, Carter Oil Co.), 1421 N. Columbia Ave., Tulsa 6, Okla.
Palmer, Robert L. (Vice-President, McCollum Exploration Co.), 853 Esperson Bldg., Houston 2, Tex.
Parker, L. A. (Office Manager, Independent Exploration Co.), Box 6007, 1922 W. Gray, Houston 6, Tex.
Parker, Richard H. (Physicist, Southwestern Industrial Electronics Co.), 1643 Kipling, Houston 6, Tex.
Parkhurst, Geo L. (President, Oronite Chemical Co.), 200 Bush St., San Francisco, Calif.
Parr, Joseph O., Jr. (Research Engineer, Petty Labs., Inc.), Box 2061, San Antonio, Tex.
Partain, Edgar S. (Observer, Seis., Stanolind Oil & Gas Co.), 3603 Gordon St., Monroe, La.
Partridge, John F., Jr. (Geologist, California Co.), 1818 Canal Bldg., New Orleans 12, La.
Paslay, L. C. (Director of Research, National Geophysical Co.), 4012 University Blvd., Dallas 5, Tex.
Paterson, R. G. (Production Engineer, Canadian West, Nat. Gas, Light, Heat & Power Co.), 215 6th Ave. West, Calgary, Alberta, Canada.
Patrick, Homer G. (In Charge of Seismic Exploration, Humble Oil & Refining Co.), Box 2180, Houston 1, Tex.
*Patterson, A. R. (Party Chief, United Geophysical Co.), Box 157, Anadarko, Okla.
Pawley, Julian K. (Geologist, Standard Oil Co. of Texas), Box 1249, Houston 1, Tex.
Payne, James E. (Geophysical Party Chief, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Peabody, Gwendolyn (Seis. Computer & Interpreter, Southern Geophysical Co.), 1003 Sinclair Bldg., Ft. Worth, Tex.
Peacock, H. B. (Vice-President, Geophysical Service, Inc.), 1416 N. Esperson Bldg., Houston 2, Tex.
Pearce, Roy W. (Structural Geologist), c/o Socony-Vacuum Oil Co. of Ven., Apartado 246, Caracas, Venezuela, S. A.
Pearson, Harry (Seismologist), c/o Caribbean Petroleum Co., Apartado 809, Caracas, Venezuela, S. A.
Peery, W. R. (Party Chief, Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
Pekeris, Chaim Leib (Research Associate, Massachusetts Inst. of Tech.), Room 316, 350 Fifth Ave., New York, N. Y.
Pillillo, M. J. (In Charge of Dallas Laboratory, Seismic Engineering Co.), 2830 Kendale Drive, Dallas, Tex.
Penny, Robert T. (Party Chief, Independent Exploration Co.), 115 So. 19th St., Baton Rouge, La.
*Pentecost, Claude D. (Party Chief, Oil Exploration, Inc.), 604 McBirney Bldg., Tulsa, Okla.
Pentz, Harold H. (Address unknown).
Peoples, J. A., Jr. (Chief of Compressional Laboratory, U. S. Army Matériel Command), P. O. Box 24, Marlboro, N. J.
Pernell, J. H. (Partner, Seismic Engineering Co.), 4954 N. W. Highway, Dallas 9, Tex.
Perret, William R. (Physicist), c/o U. S. Waterways Experiment Station, Box 631, Vicksburg, Miss.
Perry, W. B. (Geophysicist, Kingwood Oil Co.), 742 Wingfield, Jackson 40, Miss.
Perryman, J. D. (Supervisor, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
Peters, Jack W. (Chief Gravity Meter Computer, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.

Peters, Leo J. (Chief Division of Geophysical Operations, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Peterson, Raymond A. (Vice-President, United Geophysical Co.), 2279 Paloma St., Pasadena 7, Calif.
Petre, Harold D. (Party Chief, Brown Geophysical Co.), Box 6005, Houston 6, Tex.
Petty, Dabney E. (Vice-President, Petty Geophysical Engineering Co.), 10 Tenth Street, San Antonio 2, Tex.
Petty, O. S. (President, Petty Geophysical Engineering Co.), Box 2061, San Antonio 6, Tex.
Petty, Van A., Jr. (Vice-President, Petty Geophysical Engineering Co.), Box 2061, San Antonio 6, Tex.
Pezdek, Victor J. (Seismograph Operator, Western Gulf Oil Co.), P. O. Box 375, La Junta, Colo.
Pfeffer, W. J. (Gravity Supervisor), c/o Creole Petroleum Corp., Apartado 889, Caracas, Venezuela, S. A.
Phillips, Robert (Geophysicist, Geophysical Service, Inc.), 1611 Devine St., Jackson, Miss.
Pickle, Chesley B. (Instrument Engineer, Monsanto Chemical Co.), 244 Charlston Hall, Oak Ridge, Tenn.
*Pielemeier, E. A. (Vice-President, United Geophysical Co.), 595 E. Colorado St., Pasadena, Calif.
Piety, R. G. (Chief of Geophysics Section, Research Dept., Phillips Petroleum Co.), 504 Cherokee Ave., Bartlesville, Okla.
Pirson, Sylvain J. (Associate Professor, Pennsylvania State College), School of Mineral Industries, State College, Pa.
Pittman, C. V. A. (Partner, Geochemical Surveys), 3909 Miramer, Dallas, Tex.
Poldini, E. M. (Professor), University of Geneva, Geophysics Dept., Geneva, Switzerland.
Pollard, J. C. (Partner, Robert H. Hay Co.), 608 National Standard Bldg., Houston 2, Tex.
Polson, Mrs. G. S. (Computer, Geophysical Service, Inc.), Box 145, Rockport, Mo.
*Porter, C. P. (General Superintendent, Snowden Oil & Gas Co.), 7010 Coronada, Dallas, Tex.
Porter, Hugh, Jr. (Seis. Party Chief, Seismic Explorations, Inc.), Box 1127, Kingsville, Tex.
Prade, Nat H. (Seismologist), c/o Caribbean Petroleum Co., Geophysical Section, Maracaibo, Venezuela, S. A.
Pranglin, John A. (Development Engineer, Well Loggin Lab., Halliburton Oil Well Cementing Co.), P. O. Box 2535, Houston 1, Tex.
*Pratt, John F. (Party Chief, Brown Geophysical Co.), 1823 12th St., Greeley, Colo.
‡Pratt, W. E. (Director, Standard Oil Co. of N. J.), Frijole Texas Route, Box 665, Carlsbad, N. M.
Prescott, H. R. (Asst. Chief Geophysicist, Continental Oil Co.), 703 McFadden Drive, Ponca City, Okla.
Price, W. R., Jr. (Geophysicist, General Petroleum Corp.), 4015 Second Ave., Los Angeles 43, Calif.
Pugh, William E. (Senior Research Engineer, Seismograph Service Corp.), 134 E 18th St., Tulsa 5, Okla.

*Quinn, Richard F. (Computer, Independent Exploration Co.), Apt. 140-A Enfield Apts., Elizabeth City, N. C.

*Rabey, W. N. (Asst. Computer, Imperial Oil Co.), Manilla, Ontario, Canada.
Raborn, Smiley, Jr. (Field Supervisor, Mayes-Bevan Co.), Rm. 305, Kennedy Bldg., Tulsa, Okla.
*Raines, Eli (Observer, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Rait, David A., Jr. (Geophysicist, Anglo-Iranian Oil Co., Ltd.), Meadowview, Leuchars, Fife, Scotland.

*Ramaccioni, D. (Geologist & Geophysicist, Direccion General Combustibles Solidos Minerales), Chilecito (Prov. Rioja), Rep. Argentina, S. A.
Ramirez, John M. (Petroleum Geologist), c/o Corporacion de Fomento, Depto. Estudios y Planificacion, Santiago, Chile, S. A.
*Randell, John T., Jr. (Geologist, Demarara Bauxite Co., Ltd.), 4 Preston Place, Toronto 12, Ontario, Canada.
Randolf, J. R. (Asst. Seismologist, Shell Oil Co.), Box 2099, Houston 1, Tex.
*Rankin, C. T. (Gravity Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Ransom, J. H. (Party Chief, Geophysical Service, Inc.), Box 151, Williams, Calif.
Ransone, W. R. (Managing Partner, Geochemical Surveys), 3806 Cedar Springs Road, Dallas, Tex.
Raper, William B. (Gravity Supervisor, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Rasé, H. L., Jr. (Geophysicist), Gulf Res. & Dev. Co., Box 604, McComb, Miss.
Ratliff, D. W. (Seismograph Interpreter, Stanolind Oil & Gas Co.), 1810 Madison St., Lake Charles, La.
Ray, Robert H. (President, Robert H. Ray, Inc.), 608 National Standard Bldg., Houston, Tex.
Reagor, Edward C. (Partner, Geochemical Surveys), 3806 Cedar Springs Road, Dallas, Tex.
Reed, Chas. F. (Dist. Sales Manager, Dow Chemical Co.), 2205 Commerce Bldg., Houston 2, Tex.
Reed, David E. (Owner, Reed Magnetic Surveys), 1123 E. 36th Pl., Tulsa, Okla.
Reed, George W. (Supervisor, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Reed, Paul C. (Seis. Party Manager, Gulf Research & Development Co.), Box 2100, Houston 1, Tex.
Reei, C. E. (Seismologist), c/o Superior Oil Co., 930 Edison Bldg., Los Angeles 13, Calif.
Reeves, J. R. (Chief Seismologist, Lee Geophysical Exploration & Research Corp.), Box 632, Cisco, Tex.
Reichert, H. C. (Geologist, Gulf Refining Co.), Box 972, Lake Charles, La.
Reid, A. C. (Research Engineer, Stanolind Oil & Gas Co.), 1718 S. Delaware Pl., Tulsa, Okla.
Reiser, Robert G. (Development Engineer, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Renden, Hugo R. (Seismic Computer, Texas Co.), 615 1st St., Bismarck, N. D.
Renner, Darwin S. (Superintendent Electronics Lab., Geophysical Service, Inc.), 1314 Cedar Hill Ave., Dallas 8, Tex.
Rey, Pedro (Geophysicist), Depto. Exploracion, Yacimientos Petroliferos Fiscales, 777 Diagonal Roque Saenz Pena, Buenos Aires, Argentina, S. A.
Reynolds, F. F. (President, Seismic Explorations, Inc.), 2911 Gulf Bldg., Houston, Tex.
Rice, Robert B. (Mathematician, Research Dept.), c/o Phillips Petroleum Co., Research Bldg., Bartlesville, Okla.
Rich, J. M. (Gravity Meter Interpreter, Carter Oil Co.), Box 801, Tulsa, Okla.
Richards, L. J. (Computer), Geophysical Dept., Continental Oil Co., Ponca City, Okla.
Richard, T. C. (Geophysicist), c/o Anglo-Bahamian Oil Co., Ltd., Box 376, Nassau, Bahama Islands, B. W. I.
*Richardson, J. W. (Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
Rickel, Wesley K. (Party Chief, Geophysical Research Corp.), Box 2040, Tulsa 2, Okla.
Ricker, Norman H. (Sr. Research Physicist, Carter Oil Co.), 1718 E. 30th St., Tulsa, Okla.
Rieber, Frank (Owner), Rieber Research Lab., 127 E. 73rd St., New York, N. Y.
Riess, Malcolm (Party Chief, Carter Oil Co.), Box 801, Tulsa 2, Okla.
*Riley, James K., Jr. (Observer, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.

Ritzmann, O. F. (Physicist, Gulf Oil Co.), 1240 Munsey Bldg., Washington 4, D. C.
Roark, James J. (Research Engineer, Carter Oil Co.), 1218 So. Darlington, Tulsa 4, Okla.
Robert, Kearny (Partner, Southern Oil Exploration Co.), 816 Hibernia Bank Bldg., New Orleans 12, La.
Roberts, Francis A. (Seis. Party Chief, Carter Oil Co.), 10171 100-A St., Edmonton, Alberta, Canada.
Roberts, Homer E. (Seismic Computer, Petty Geophysical Engineering Co.), Box 2061, San Antonio 6, Tex.
Roberts, Louin W. (Chief Computer, Petty Geophysical Engineering Co.), Box 2061, San Antonio 6, Tex.
Robertson, Florence (Asst. Professor of Geophysics, St. Louis University), 4349 Forest Park Blvd., St. Louis 8, Mo.
Robertson, K. A. (Supervisor, United Geophysical Co.), 822 Thompson Bldg., Tulsa 3, Okla.
*Robinson, Edwin H. (Maj. U. S. Army Corps of Engineers), c/o Mrs. W. K. Young, 2108 Smith St., Houston, Tex.
*Robinson, George W. (Observer, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
*Robinson, John L., Jr. (Geophysicist, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Robinson, W. Bernard (Geophysicist, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Rojas, A. Garcia (Geophysicist, Petroleos Mexicanos), Ramon Alcazar #6, Mexico City, D. F.
Rollins, J. Frank (Supervisor, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Rollins, J. C. (Supervisor Interpretation Section, C. H. Frost Gravimetric Surveys, Inc.), Box 58, Tulsa, Okla.
Rolshausen, F. W. (Chief Paleontologist), c/o Humble Oil & Refining Co., P. O. Box 2180, Houston 1, Tex.
Romberg, Frederick E. (Lab. Superintendent, LaCoste & Romberg), 3810 Speedway, Austin, Tex.
Romberg, Marvin (Computer, Carter Oil Co.), Box 801, Tulsa, Okla.
*Roos, Lewis V. (Party Chief, Texas Co.), Box 2332, Houston 1, Tex.
Rosaire, E. E. (Consulting Geophysicist), 2711 Westheimer Rd., Houston 6, Tex.
Rose, H. W. (Staff Geophysicist), c/o Sun Oil Company, P. O. Box 2880, Dallas 1, Tex.
Rosenkrans, Robert R. (Field Supervisor, Seismic Explorations, Inc.), 3439 Broadmoor Blvd., Shreveport, La.
Ross, Charles M. (Seis. Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
Ross, John W. (Field Supervisor, C. H. Frost Gravimetric Surveys, Inc.), 1023 E. 36th Pl., Tulsa, Okla.
Ross, Ralph B. (Geophysicist, Gulf Research & Development Co.), Box 661, Tulsa, Okla.
Roy, Chalmer J. (Assoc. Professor of Economic Geology), School of Geology, Louisiana State University, Baton Rouge 3, La.
Rozlosnik, Andres (Chief of Exploration Dept., Yacimientos Petroleos Fiscales), Cordoba 612, 6° Pisa Departmento A., Buenos Aires, Argentina, S. A.
Rozsa, Theodore (Sr. Seismologist, Shell Oil Co., Inc.), Box 1817, Jackson, Miss.
Rudolph, P. J. (Operations Manager, Petty Geophysical Engineering Co.), Box 2061, San Antonio, Tex.
*Rugg, Allen M., Jr. (Draftsman, Post Engineer, Ladd Field), Box 706, Fairbanks, Alaska.
Ruhlen, W. W. (Permitman, Gulf Research & Development Co.), 420 S. Willow St., Pecos, Tex.
Rummerfield, Ben F. (Geophysical Supervisor), c/o Seismograph Service Corp. of Dela., Apartado 1488, Caracas, Venezuela, S. A.
*Rumsey, Nelson J., Jr. (Address unknown).
Rumsey, Paul T. (Seismologist, Petty Geophysical Engineering Co.), 2425 Southgate, Houston 5, Tex.

Rupnik, John J. (Geophysicist, Sinclair-Prairie Oil Co.), Box 521, Geol. Dept., Tulsa, 2, Okla.
Rusch, Peter J. (Seismologist, L. J. Neuman Co.), Box 1832, Houston, Tex.
Ruska, Walter, E. A. (President & General Manager, Ruska, Instrument Corp), 3910 Driscoll St , Houston 6, Tex.
*Russek, I. W. (Seismic Computer, Magnolia Pet. Co.), Box 349, Morgan City, La.
Russell, Dallas L. (Party Chief, Geophysical Service, Inc.), Box 1512, McAllen, Tex.
Rust, William M., Jr. (Head of Geophysics Research, Humble Oil & Refining Co.), 257 Humble Bldg., Houston 1, Tex.
Rutherford, Homer (Consulting Geologist), Box 94, Mt. Vernon, Ill.
Rutledge, Richard B. (Division Geologist, Skelly Oil Co.), 708 Skelly Bldg., Box 1650, Tulsa 2, Okla.

St. Clair, D. W. (Geologist, Los Nietos Company), Box 1459, Midland, Tex.
Sagoci, Hilmi F. (Computer), c/o Maden Tetkik ve Arama Enstitüsü, Ankara, Turkey.
Salvatori, Henry (President, Western Geophysical Co.), 711 Edison Bldg., Los Angeles 13, Calif.
Sanders, C. W. (Chief Geologist, Danciger Oil & Refining Co.), 2413 Colonial Parkway, Ft. Worth 4, Tex.
Sappington, Chester (Vice-President, General Geophysical Co.), 2514 Gulf Bldg., Houston, Tex.
Sargent, Raymond L. (Owner, Raymond L. Sargent Magnetometer Surveys), 623 M. & M. Bldg., Houston 2, Tex.
Sauls, James L., Jr., 2210 Bissonet St., Houston, Tex.
Saunders, L. W. (Vice-President, Independent Exploration Co. of Calif.), 531 California Ave., Bakersfield, Calif.
Sauvé, Nathaniel B. (Chief Geophysicist, Netherlans Koloniale Pet. Mitj.), Rm. 635 26 Broadway, New York 4, N. Y.
Saville, W. G. (Sr. Partner, Gravity Meter Exploration Co.), 1348 Mellie Esperson Bldg., Houston 2, Tex.
Schaeffer, Hugh C. (President, North American Geophysical Co.), 2627 Westheimer, Houston 6, Tex.
Schafer, Sidney (Consulting Geophysicist), 3775 Harper, Houston 5, Tex.
Scharon, Harry LeRoy (Geophysicist, U. S. Geological Survey), 203 Custom House, Baltimore 2, Md.
Schauble, C. G. (Party Chief), c/o Seismograph Service Corp. of Dela.), Apartado Aereo 4000, Bogota, Colombia, S. A.
Schempf, Edward G. (Vice-President & Manager of Operations), c/o United Geophysical Co., Inc., 595 E. Colorado Street, Pasadena 1, Calif.
*Scherb, Ivan V. (Geophysical Computer, Texas Co.), 247 Peck Drive, Beverly Hills, Calif.
Schiflett, H. L. (Manager & Partner, States Exploration Co.), Box 845, Sherman, Tex.,
Schlumberger, Marcel (President, Compagnie Générale de Geophysique), 42 rue St. Dominique, Paris, France.
Schmidt, Henry (Fleet Superintendent, Independent Exploration Co.), 311 E. Cowan Drive, Houston 7, Tex.
*Schmidt, K. H., Jr. (Owner, Petroleum Service Co.), Alamo National Bldg., San Antonio, Tex.
Schmuck, R. H. (Seismograph Operator), c/o Humble Oil & Refining Co., 202 Humble Bldg., Houston, Tex.
Schoellhorn, S. Wm. (Party Chief, Seismograph Service Corp.), Apartado 1488, Caracas, Venezuela, S. A.
Schofield, G. A. (Party Chief, Texas Co.), Box 2332, Geophysical Div. Houston 1, Tex.
Scholl, Louis A., Jr. (Manager Geophysical Division, Texas Co.), 2232 Stanmore Drive, Houston 6, Tex.
Schombel, L. F. (Seismologist, Shell Oil Co.), Box 389, Kemmerer, Wyo.
Schouten, F. H. (Senior Geologist, Stanolind Oil & Gas Co.), Box 1410, Ft. Worth, Tex.
Schriever, William (Director of School of Engineering Physics), c/o University of Oklahoma, Norman, Okla.

Schultis, G. E. (Party Chief, Carter Oil Co.), c/o Creole Petroleum Corp., Apartado 1329, Caracas, Venezuela, S. A.
Schumacher, J. P. (Senior Partner, Gravity Meter Exploration Co.), 1348 Esperson Bldg., Houston 2, Tex.
Schwennesen, A. T. (Geologist), c/o Socony-Vacuum Oil Co., 62 Sharia Ibrahim Pasha, Cairo, Egypt.
Scott, C. B. (Research Engineer, Carter Oil Co.), 2527 S. Evanston St., Tulsa 5, Okla.
Scott, D. L. (Party Chief, Gulf Research & Development Co.), Box T-261, Ozona, Tex.
Scott, David H. (Geologist, Texas Co.), Rm. 6, Kern Co. Land Bldg., 1700 19th St., Bakersfield, Calif.
Seager, O. A. (Asst. Manager), Standard Oil Co., of Egypt, 22 Sharia Kasr el Nil, Cairo, Egypt.
Seaman, L. O. (In Charge of Geophysical Work), c/o Sinclair Prairie Oil Co., Box 521, Tulsa 2, Okla.
Searcy, Frank (Development Engineer), Geophysical Div., Continental Oil Co., Ponca City, Okla.
Seifert, Wesley H. (Seismic Party Chief, Magnolia Petroleum Co.), Box 900, Dallas 1, Tex.
Seiler, George E. (Observer, Geotechnical Corp.), 1702 Tower Petroleum Bldg., Dallas 1, Tex.
Selig, A. L. (Consulting Geologist), 5118 Grantwood, Houston 4, Tex.
†Selmser, Calbert B. (Graduate Student, University of Toronto), 45 Lansdowne St., Sudbury, Ontario, Canada.
Serviss, Fred L. (Professor of Geology), Purdue University, LaFayette, Ind.
Shackelford, Lewis L., Jr., 320 College St., Waxahachie, Tex.
Shade, N. R. (Chief Geophysicist, General Petroleum Corp.), 3747 Effingham Pl., Los Angeles 27, Calif.
Shafer, Russell E. (Manager, Cary Iron Works), Box 469, Opelousas, La.
Shapard, Charles A. (Credit Manager, Sears Roebuck & Co.), 1320 E. Black, Gulfport, Miss.
Sharp, C. Sheldon (Supervisor, Brown Geophysical Co.), 213 Stratford St., Houston 6, Tex.
Sharpe, Joseph A. (Vice-President, C. H. Frost Gravimetric Surveys, Inc.), Box 58, Tulsa 1, Okla.
Shaw, Herman (Keeper of Dept. of Physics & Geophysics), The Science Museum, South Kensington, London SW 7, England.
Sheffet, David (Director of Research, Western Geophysical Co.), 1883 Corson St., Pasadena 8, Calif.
Shell, H. E. (Party Chief, Superior Oil Co.), Box 510, Midland, Tex.
Shepherd, Cuth K. (Seis. Party Chief, Continental Oil Co.), 4005 Hanover, Dallas, Tex.
Sherar, E. S. (Chief Geophysicist, Tide Water Assoc. Oil Co.), P. O. Box 1404, Houston 1, Tex.
Sherar, Stuart (Independent Geophysicist), 1307 Esperson Bldg., Houston 2, Tex.
Shimek, E. Joe (Partner, Geophysical Associates), Box 6005, Houston 6, Tex.
Shock, Lorenz I. (District Supervisor, National Geophysical Co.), 621 N. VanBuren, San Angelo, Tex.
Shore, Harold F. (Superior, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Short, Don C. (Party Chief, United Geophysical Co.), 595 E. Colorado St., Pasadena 1, Calif.
Shugart, T. R. (Supervisor, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
Sibley, W. B. (Research Engineer), c/o Seismograph Service Corp., Box 228, Cairo, Egypt.
Siegel, Frank (Seismic Interpreter), c/o Sun Oil Company, Box 2831, Beaumont, Tex.
Siegert, Arnold J. F. (Associate Professor), Dept. of Physics, Syracuse University, Syracuse 10, N. Y.
*Silva, Will (Acting Party Chief), c/o Texas Petroleum Co., Aptdo. Nacional 1877, Bogota, Colombia, S. A.

Silverman, Daniel (Exploration Research Supervisor, Stanolind Oil & Gas Co.), 3638 So. Wheeling St., Tulsa, Okla.
*Sims, Sam E. (Geophysicist, American Republics Corp.), 1812 Petroleum Bldg., Houston 2, Tex.
Sisson, Harry H. (Geologist, Gulf Oil Corp.), Box 6, Palacios, Tex.
Skeels, D. Covell (Research Geophysicist), c/o Standard Oil Co. of N. J., 30 Rockefeller Plaza, New York, N. Y.
Sklar, Maurice (Seismologist), c/o Shell Oil Co., Inc., Box 1509, Midland, Tex.
Slichter, Louis B. (Professor of Geophysics), Dept. of Geology, University of Wisconsin, Madison, Wis.
Sloat, John (Geophysicist, Union Oil Co. of Calif.), 511 F. St., Bakersfield, Calif.
Slotnick, M. M. (Supervisor), c/o Humble Oil & Refining Co., Box 2180, Houston 1, Tex.
Smiley, W. G., Jr. (Research Computer, Sun Oil Co.), Box 2661, Beaumont, Tex.
Smith, Aylwin L. (Vice-President, Independent Exploration Co.), Box 6007, Houston 6, Tex.
Smith, Cyril B. (Geophysicist, Sohio Petroleum Co.), 2300 1st National Bank Bldg., Oklahoma City, Okla.
Smith, D. F. (Partner, Oklahoma Geophysical Co.), 807 N. Louisa St., Shawnee, Okla.
*Smith, Douglas H. (Geophysicist, Gulf Research & Development Co.), c/o Mene Grande Oil Co., Aptdo. 45, Barcelona, Venezuela, S. A.
*Smith, Francis E. (Office Computer), Kerr-McGee Oil Ind., Inc., Oklahoma City 2, Okla.
Smith, Frank B. (Secretary-Treasurer, Republic Exploration Co.), Box 2208, Tulsa, Okla.
Smith, J. Angelo (Seis. Development Engineer), c/o Humble Oil & Refining Co., Houston, Tex.
Smith, James A. (Party Chief, United Geophysical Co.), Aptdo. Aereo 3439, Bogota, Colombia, S. A.
Smith, Neal J. (Superintendent Geophysics Division, California Co.), 1818 Canal Bldg., New Orleans 12, La.
Smith, Noyes D. (Manager, Physical Dept.), c/o Shell Exploration & Production Lab., 3705 Bellaire Blvd., Houston 5, Tex.
Smith, Randolph (Computer, Geotechnical Corp.), Box 7166, Dallas 9, Tex.
Smith, Warren H. (Computer, Texas Co.), 1500 Broadway Tower Bldg., Enid, Okla.
Smith, W. Gordon (Seismologist), c/o Caribbean Petroleum Corp., Maracaibo, Venezuela, S. A.
*Smitherman, Lynn A. (Seis. Computer, Petty Geophysical Engineering Co.), Box 67, Athens, Tex.
Smithwick, H. B. (Party Chief, Atlantic Refining Co.), Box 2819, Dallas 1, Tex.
Snedden, Loring B. (District Geologist, Texas Co)., Rm. 6, Kern Co. Land Co. Bldg., Bakersfield, Calif.
Snow, Arthur Leland (Seismologist), c/o Petty Geophysical Co., Box 2061, San Antonio Tex.
Sohlberg, R. G. (Geophysicist), c/o Richmond Exploration Co., Tienda Honda a Puenta 61, Caracas, Venezuela, S. A.
Somers, George B. (Asst. Prof. of Geology, University of Houston), 4380 Wheeler Ave., Houston, Tex.
Sorge, B. W. (Supervisor, United Geophysical Co.), 1065 Kendall Dr., San Gabriel, Calif.
Sorrells, B. J. (Supervisor, National Geophysical Co.), 606 E. Brazos St., Victoria, Tex.
Soske, Joshua L. (President and Chief Geophysicist, Geophysical Engineering Corp.), Box 7, Sta. C., Pasadena, Calif.
Souther, J. B. (Consulting Geologist & Geophysicist), 1930 F St., Lincoln, Nebr.
*Southgate, Tom F. (Chief Computer, Amerada Petroleum Corp.), Box 2040, Tulsa, Okla.
Sparks, Neil R. (Seismologist, Stanolind Oil & Gas Co.), 1114 S. Urbana St., Tulsa, Okla.
†Spearing, Edwin W. (Student, University of Tulsa), 2715 E. 10th St., Tulsa, Okla.

Speirs, Geo H. (President, Seismograph Service Corp. of Dela.), Apartado 1488, Caracas, Venezuela, S. A.
Spencer, Leslie C. (District Geophysicist, Atlantic Refining Co.), 1001 City Bank Bldg., Shreveport, La.
Sprague, Robert L. (Computer), c/o The Superior Oil Co., Seis. Party #8, Los Angeles, Calif.
Sproule, J. C. (Division Geologist), c/o International Petroleum Co., 56 Church St., Toronto, Ontario, Canada
Stafford, C. J. (Consulting Geologist & Geophysicist), P. O. Box 232, Lusk, Wyo.
Stanton, Austin N. (Chief Engineer), c/o Varo Mfg. Co., Box 686, Garland, Tex.
Staples, Guy W. (Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Starr, A. G. (Seismograph Computer, Humble Oil & Refining Co.), 202 Humble Bldg., Houston 1, Tex.
Statham, Louis (Physicist, Statham Labs.), 8222 Beverly Blvd., Los Angeles 36, Calif.
Stern, Noel H. (Vice-President, W. C. McBride Inc.), 2101 Missouri Pacific Bldg. St. Louis, Mo.
Steel, D. M. (Party Chief, Geotechnical Corp., 1702 Tower Petroleum Bldg., Dallas 1, Tex.
Steele, W. E., Jr. (Geophysicist), 2118 Elmen, Houston, Tex.
Stehr, Raymond A. (Chief Geologist, Seaboard Oil Co.), 1400 Continental Bldg., Dallas, Tex.
Stewart, S. B. (Party Chief, Keystone Exploration Co.), 7431 Magnolia, Houston 12, Tex.
Stick, John C., Jr. (Electrical Engineer, Lane-Wells Co.), 5611 South Soto St., Los Angeles 11, Calif.
Stiles, Elisabeth, Circle S. Ranch, Hamilton, Tex.
*Stimler, Saul (Observer, Seismograph Service Corp.), Apartado 4000, Bogota, Colombia, S. A.
*Stommel, Harrison E., Dept. of Geophysics, Colorado School of Mines, Golden, Colo.
Stone, George B. (Geologist-Geophysicist, Phillips Petroleum Co.), 2111 Dunstan Road, Houston, Tex.
Stones, J. Eugene (Seis. Party Chief), c/o Superior Oil Co., P. O. Box 652, Chickasha, Okla.
Storm, Alfred E. (Party Chief, Geophysical Service, Inc.), 6000 Lemmon Ave., Dallas 1, Tex.
Stotler, Thomas C. (Gravity Meter Computer, Stanolind Oil & Gas Co.), 234 S. Sandusky, Tulsa 4, Okla.
Stover, Edward B., Jr. (Geophysical Research Engineer, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.
Strachan, Clyde G. (Geologist), c/o Gulf Oil Corp., Geological Dept., Box 661, Tulsa 5, Okla.
Straley, H. W., III (Consulting Geologist & Geophysicist), Box 5532, Friendship Station, D. C.
Strange, Booth B. (Party Chief), c/o Western Geophysical Co., Box 596, Natchez, Miss.
Strange, O. A. (Party Chief), c/o Western Geophysical Co., Box 596, Natchez, Miss.
Stratton, Everett F. (Exploitation Manager, Schlumberger Well Surveying Co.), Box 2175, Houston, Tex.
*Strong, John R., Jr. (Supervisor, Leonard J. Neuman), 943 Esperson Bldg., Houston, Tex.
Stubbe, Gerhard, (24a) Langeloh b. Tostedt Kr. Harburg, British Zone, Germany.
Stulken, Edgar J. (Siesmologist, Geophysical Service, Inc.), 5010 Airline Rd., Dallas 5, Tex.
Sturdevant, John M. (Party Chief, Geophysical Service, Inc.), Box 823, Houma, La.
Suggs, Millard L. (Field Supervisor, Magnetex Geophysical Co.), 604 Burk Burnett Bldg., Ft. Worth 2, Tex.
Sundt, O. F. (Petroleum Attache, U. S. Department of State), c/o United States Embassy, Lima, Peru, S. A.

Swan, Bird G. (Control Geophysicist), c/o Continental Oil Co., Geophysical Div., Ponca City, Okla.
Swartz, Charles A. (Geophysicist, Union Oil Co. of Calif.), 1134 Commerce Bldg., Houston, Tex.
Swartz, J. H. (Geophysicist in Charge of Baltimore Unit, U. S. Geological Survey), Section of Geophysics, U. S. Geological Survey, 203 Custom House, Baltimore 2, Md.
Swearingen, A. C. (Gravity Meter Party Chief, Stanolind Oil & Gas Co.), Gravity Meter Dept., Box 591, Tulsa 2, Okla.
Sweet, Elliott (President, Sweet Geophysical Co.), 334 Tenth St., Santa Monica, Calif.
Sweet, R. C. (Vice-President, North American Geophysical Co.), 2627 Westheimer, Houston 6, Tex.
Sype, William R. (Geologist), c/o Stanolind Oil & Gas Co., Box 591, Tulsa, Okla.

Tallman, R. H. (Gravity Meter Party Chief), c/o Tropical Oil Co., Bogota, Colombia, S. A.
Tarrant, L. H. (Geophysicist, Anglo-Iranian Oil Co., Ltd.), 73 Parliament Hill, Hampstead, London N.W. 3, England.
Taylor, Albert (Party Chief, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
Taylor, DeWitt E. (Senior Geologist, Shell Oil Co., Inc.), 209 Topaz, Balboa, Calif.
Taylor, Garvin L. (Geological Supervisor, Geophysical Dept., Stanolind Oil & Gas Co., Tulsa, Okla.), 3116 So. Madison, Tulsa 5, Okla.
Taylor, John E. (Engineer), c/o Arkansas Natural Companies, Slattery Bldg., Shreveport, La.
Taylor, W. H. (President, Taylor Exploration Co.), 1601 So. Shepherd, Apt. 123, Houston 6, Tex.
Tefft, Gerald H. (Geologist), Stanoline Oil and Gas Co.), P. O. Box 660, Tyler, Tex.
Templeton, James C. (Managing Director), c/o Geophysical Prospecting Co., 6 Neville Ct. Abbey Rd., London N.W. 8, England.
Terry, Melvin C. (Research Geophysicist), c/o Humble Oil & Refining Co., Houston, Tex.
Terry, R. D. (Party Chief, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas, Tex.
Teufel, Virgil W. (Party Chief, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas, Tex.
Texter, John W. (Interpreter, Gulf Research & Development Co.), P. O. Drawer 2038, Pittsburgh 30, Pa.
Thomas, Earl (Party Chief, Geophysical Service, Inc.), Box 72, Maypearl, Tex.
Thomas, J. W. (Supervisor, Geophysical Service, Inc.), Monte Himalaya 1015, Lomas da Chapultepec, Mexico, D. F.
*Thomas, J. W., Jr. (Observer), c/o Stanolind Oil & Gas Co., Box 5686, Sonora, Tex.
*Thomas, T. J. (Field Supervisor, Gravity, Barnsdall Oil Co.), Box 2039, Tulsa, Okla.
*Thompson, Grady (Manager & Co-Owner, Thompson Powder Co., Inc.), Box 505, Hobbs, N. M.
Thompson, R. R. (Research Geophysicist), c/o Humble Oil & Refining Co., Houston, Tex.
Thompson, R. P. (Party Chief, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
Thomsen, Erik (Seis. Interpreter), c/o Stanolind Oil & Gas Co., Box 1410, Ft. Worth, Tex.
Thomsen, Harry L. (Senior Seismologist), c/o Shell Oil Co., Inc., Box 720, Casper, Wyo.
Thornburgh, H. R. (Geophysicist, Shell Oil Co., Inc.), 2310 Paloma St., Pasadena 7, Calif.
Thralls, H. M. (Supervisor, Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
*Tilleux, Harry O. (Geologist, Heiland Exploration Co.), 630 Giddens Lane Bldg., Shreveport, La.
Tilley, Aubra E. (Electrical Engineer, Phillips Petroleum Co.), 303 Quapaw, Bartlesville, Okla.
Todd, James H. (Geologist, California Co.), 125 North Jackson, Brookhaven, Miss.

Tomlinson, John B. (Party Manager, Gulf Research & Development Co.), Box 167, Laurel, Miss.
Tompkins, Frederick A. (Asst. to General Superintendent, Paper Div., Eastman Kodak Co.), 77 Lake Crest Road, Rochester 12, N. Y.
Totten, Stanley W. (Geologist), c/o California Co., 1818 Canal Bldg., New Orleans 12, La.
Tottenham, W. M. (Seismograph Party Chief, Magnolia Petroleum Co.), Box 900, Dallas, Tex.
Treybig, B. H., Jr. (Geophysical Supervisor), c/o Texas Co., Box 252, New Orleans 9, La.
Tribbey, R. J., Jr. (Party Chief, Socony-Vacuum Oil Co.), Apartado 246 Seis. Crew #3, Caracas, Venezuela, S. A.
Tripp, R. Maurice (Consulting Geophysicist), Trapelo Road, Lincoln, Mass.
Trombla, Lynn B. (Supervisor of Seismograph, Superior Oil Co.), 2211 Apco Tower, Oklahoma City, Okla.
Tucker, M. D. (Seis. Party Chief, Stanolind Oil & Gas Co.), Box 659, Casper, Wyo.
Tucker, Paul M. (Geophysicist), c/o Standard Oil Co. of Cuba, Apartado 1303, Havana Cuba.
Tucker, R. H. (President, Tucker Exploration Co.), 403 Tuloma Bldg., Tulsa, Okla.
Tucker, Robert L., Jr. (Office Computer), c/o Magnolia Petroleum Corp., Box 56, Houston 1, Tex.
Turner, Dale E. (Seismologist, Superior Oil Co.), 1151 Heather Sq., Pasadena 6, Calif.

Uhrig, Leonard F. (Seismologist, Shell Oil Co., Inc.), 3801 Villanova, Houston 5, Tex.
Ulrich, Victor P. (Geophysicist, N. V. Bataapke Pet. Co.), Dedelstraat 13, The Hague, Netherlands.
Unger, Earle E. (Geophysicist, Gulf Research & Development Co.), 3620 Plumb St., Houston 5, Tex.
*Urban, L. M. (Observer, Independent Exploration Co.), Box 6007, Houtson 6, Tex.
Urick, Robert J. (Associate Physicist), Sound Div., Naval Research Lab., Washington 20, D. C.

*Valkus, James W. (Map Draftsman, Atlantic Refining Co.), 6652 Avalon Ave., Dallas 14, Tex.
Vallat, E. H. (District Geologist, The Ohio Oil Co.), 208 Lincoln St., Bakersfield, Calif.
Van Beveren, O. F. (Geophysical Supervisor, Standard Oil Co. of Calif.), Box 1200, Bakersfield, Calif.
Van Cleave, R. F. (Dist. Seismic Supervisor, Atlantic Refining Co.), 91 Beauregarde Ave., Maplewood, La.
van der Linden, E. J. P. (Managing Director, Seismograph Service, Ltd.), 3a London Wall Bldg., London, E.C. 2, England.
van Melle, F. A. (Research Seismologist, Shell Oil Co., Inc.), 3721 Tangley, Houston 5, Tex.
Van Orstrand, C. E. (Geophysicist), Route 2, Manito, Ill.
Van Steenbergh, S. K. (Supervisor), c/o Sinclair Prairie Oil Co., 901 Fair Bldg., Ft. Worth 2, Tex.
Van Weelden, A. (Chief Geophysicist), c/o N. V. de Bataafsche Pet. Maatschappij, 30 Carel van Bylandtlaan, The Hague, Holland.
Vernon, Jess (Geologist, Amerada Petroleum Co.), Box 2040, Tulsa 2, Okla.
Von Croy, Stefan (Chief Geophysicist), c/o Barnsdall Oil Co., Box 2039, Tulsa 2, Okla.
Vorheis, Byron (Development Engineer, Geophysics, Continental Oil Co.), 1214 S. Sixth, Ponca City, Okla.

Waddell, V. H. (Party Chief, Western Geophysical Co.), Box 204, Wiggins, Miss.
Waggoner, J. Woodrow (Partner, Southern Oil Exploration Co.), 816 Hibernia Bank Bldg., New Orleans 12, La.
Wagoner, George E. (Exploration Manager, Southern Div., Carter Oil Co.), Drawer 1739, Shreveport, La.
Wahl, Carl C. (Observer-Recorder, Superior Oil Co.), Eustis, Nebr.

[4]Waldrep, W. Day (Chief Geophysical Draftsman, Stanolind Oil & Gas Co.), Box 1094, Tulsa, Okla.
Walker, J. E. (Seismologist, Shell Oil Co., Inc.), Box 789, Shreveport, La.
Walker, J. R. (Head of Geophysical Department, Ark. Fuel Oil Co.), Box 1734, Shreveport, La.
Walling, F. Rex, Jr. (Party Chief, Stanolind Oil & Gas Co.), Box 812, Mansfield, La.
Wallace, C. R. (Supervisor of Field Operations, Texas Co.), c/o Mr. L. A. Scholl, Jr., Box 2332, Houston 1, Tex.
Waller, J. A., Jr. (Computer, Geotechnical Corp.), 1702 Tower Pet. Bldg., Dallas 1, Tex.
Walling, Dean (Vice-President), c/o Western Geophysical Co., 711 Edison Bldg., Los Angeles, Calif.
Walling, Ray W. (Seismic Party Chief), c/o Stanolind Oil & Gas Co., Box 591, Tulsa, Okla.
Wallis, Wm. E. (General Manager), c/o International Petroleum Co., Ltd., Apt. 1081, Lima, Peru, S. A.
Walsh, T. N. (Lab. Technician, Geophysical Service, Inc.), 4113 Hyer, Apt. 29, Dallas 5, Tex.
Walter, E. J. (Associate Professor of Mathematics), c/o John Carroll University, University Heights, Cleveland 18, Ohio.
Walton, Britain W. (Consultant), 5305½ Jackson St., Houston, Tex.
Walton, George G. (Seis. Party Chief, Carter Oil Co.), Box 721, Texarkana, Tex.
*Walton, J. I. (Engineer, Carter Oil Co.), 1340 E. 17th St., Tulsa 5, Okla.
Wantland, Dart (Geophysicist, Geology Sect., U. S. Bureau of Reclamation), 1664 Harrison St., Denver, Colo.
*Ward, Dwight E. (Computer, Carter Oil Co.), 521 So. Elwood Ave., Tulsa 5, Okla.
Warren, Kirby J. (Computer), c/o Sinclair Prairie Oil Co., 901 Fair Bldg., Fort Worth, Tex.
Warren, Paul R. (Supervisor, Continental Oil Co.), Box 569, Lafayette, La.
Waterfall, Louis N. (Chief Geologist, Union Oil Co. of Calif.), 1105 Hillcroft Rd., Glendale, Calif.
Waterman, Joseph C. (Senior Seismologist, Shell Oil Co., Inc.), Box 999, Bakersfield, Calif.
Waters, Kenneth H. (Supervisor, National Geophysical Co.), 7618 Roper St., Dallas 9, Tex.
Watson, George R. (Geophysicist, Gulf Research & Development Co.), Box 2038, Pittsburgh 30, Pa.
Watson, Robert J. (Exploration Manager, Standard Oil Co. (Bahamas) Ltd.), Box 1105, Nassau, Bahamas.
Watt, J. S. (Research Specialist, Humble Oil & Refining Co.), 261 Humble Bldg., Houston, Tex.
Weatherburn, K. R. (Geophysicist), c/o Shell Oil Co., Inc., Geophysical Lab., 3705 Bellaire Blvd., Houston, Tex.
Weatherby, B. B. (Vice-President, Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
Weatherby, S. Preston (Geophysicist, Southern Minerals Corp.), 411 No. Broadway, Corpus Christi, Tex.
Weaver, Paul (Chief Geophysicist, Gulf Oil Corp.), Drawer 2100, Houston 1, Tex.
Weber, David M. (Geophysicist, Gulf Research & Development Co.), c/o Mene Grande Oil Co., Apartado 234, Maracaibo, Venezuela, S. A.
Webster, Felix H. (Chief Geophysical inspector, La. Dept. of Wild Life & Fisheries), 3962 Cambronne Street, New Orleans, La.
Weg, Klaas V. D., 324 Panoramic Way, Berkeley 4, Calif.
Weichert, R. F., Jr. (Geophysical Co-ordinator), c/o Standard Oil Co. (N. J.), 30 Rockefeller Plaza, New York 20, N. Y.
Weingartner, R. A. (Senior Geologist, Stanolind Oil & Gas Co.), Box 591, Tulsa, Okla.
Weinzierl, Jno. F. (Consulting Geologist & Geophysicist), Lauratal, Riverside, Walker County, Tex.

Weisbrich, R. A. (Geophysicist), c/o Petty Geophysical Company, Casilla 320, Ambato, Ecuador, S. A.
Weiss, Oscar (Consulting Geophysicist), 902 S. A. Mutual Bldg., Commissioner St., Johannesburg, Union of South Africa.
Wells, William M. (Consulting Geophysicist), Wells Gravity Surveys, 209 Hunter Bldg., Shreveport 69, La.
Wenz, Gordon M. (Physicist, U. S. Navy Electronics Lab.), Box 479, Point Loma Station, San Diego 6, Calif.
Wert, Carl M. (Seis. Party Manager), c/o Gulf Research & Development Co., Box 2038, Pittsburgh 30, Pa.
West, S. Stewart (Asst. Professor of Physics, University of Alaska), Box 2, College, Alaska.
West, Thomas S. (Geologist & Geophysicist, Blanco Oil Co.), 2115 Alamo National Bldg., San Antonio, Tex.
Westby, G. H. (President, Seismograph Service Corp.), Box 1590, Tulsa 1, Okla.
Westrick, Edmond W. (Geophysicist, Gulf Research & Development Co.), Drawer 2038, Pittsburgh 30, Pa.
Wetzel, W. W. (Physicist, Minnesota Mining & Manufacturing Co.), 501 Pelham Blvd., St. Paul, Minn.
*Whelan, Mark (Independent Geophysicist), 1002 S. Roselawn, Artesia, N. M.
White, Gifford E. (East Coast Representative, Statham Laboratories), 200 St. Pauls Rd. N., Hempstead, N. Y.
White, Rex H. (Seismic Supervisor, Magnolia Petroleum Co.), 417 Redell St., Garland, Tex.
White, Stanley A. (Party Chief, Independent Exploration Co.), 901 Experson Bldg., Houston 2, Tex.
Whitehead, Loren E. (Supervisor), c/o Continental Oil Co., Ponca City, Okla.
Whitley, W. M. (Party Chief, Nance Exploration Co.), Box 774, Hattiesburg, Miss.
Whiton, Herman F. (President, Union Sulphur Co.), 33 Rector Street, New York, N. Y.
Whitsitt, Charles D. (Gulf Coast Supervisor, Petty Geophysical Engineering Co.), 1449 Esperson Bldg., Houston 2, Tex.
*Wiancko, Eugene. (Address unknown).
*Wickerham, M. D. (Party Manager, Gulf Research & Development Co.), Box 2038, Pittsburgh, Pa.
Widess, M. B. (Geophysicist, Stanolind Oil & Gas Co.), 2422 E. 19th St., Tulsa 4, Okla.
*Wilber, Roscoe C., Jr. (Computer, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Wilcox, Stanley W. (Director of Public Relations, Seismograph Service Corp.), Box 1590, Tulsa 3, Okla.
*Wiley, W. B. (Seis, Party Manager, Gulf Research & Development Co.), 158 Ridgewood Drive, Metairie, New Orleans, La.
*Wilkinson, A. L. (Gravity Meter Party Chief, Petty Geophysical Engineering Co.), Box 2061, San Antonio, Tex.
*Wilkinson, R. P. (Asst. Geophysicist, Anglo-Bahamian Petroleum Co., Ltd.), P. O. Box 376, Nassau N.P. Bahamas.
Williams, C. E. (Recorder), c/o American Exploration Co., Houston, Tex.
Williams, Charles C. (Geologist), c/o Siesmic Engineering Co., Lafayette, La.
Williams, E. Darrell (Consulting Seismologist), 2732 Pittsburgh St., Houston 5, Tex.
Williams, Floyd J. (Seismologist, Geophysical Service, Inc.), 6000 Lemmon Ave., Dallas 9, Tex.
Williams, P. S. (Chief of Research, Carter Oil Co.), 3016 S. Madison, Tulsa 5, Okla.
Williams, Richard (Partner, Seismic Engineering Co.), 404 Crockett Rd., Palestine, Tex.
*Williamson, Lonnie C. (Radio Technician, Independent Exploration Co.), 1922 W. Gray, Houston, Tex.
Williston, Samuel H. (Vice-President in Charge of Operations, Cordero Mining Co. & Horse Heaven Mines, Inc.), 702–4 Mechanics Inst. Bldg., 57 Post St., San Francisco 4, Calif.

Willis, Floyd, Jr. (Engineer, Naval Ordnance Lab.), 135 Joliet St. S.W., Washington 20, D. C.
Wilson, Clyde H. (Mining Engineer), Apt. #2, 170 S. Mountain View Ave., Los Angeles 4, Calif.
Wilson, E. E. (Seis. Party Chief, Geotechnical Corp.), 1702 Tower Petroleum Bldg., Dallas 1, Tex.
*Wilson, James N. (Party Chief, Seismograph Service Corp.), Box 1590, Tulsa, Okla.
Wilson, John H. (Vice-President, Independent Exploration Co.), 1411 Electric Bldg., Ft. Worth 2, Tex.
Wilson, Richard M. (Geologist, Ohio Oil Co.), Box 1129, Shreveport, La.
Winfrey, D. B. (Party Chief, Petty Geophysical Engineering Co.), Box 651, Casper, Wyo.
Wingett, R. O. (Geophysicist, Union Oil Co. of Calif.), 2411 Crawford St., Apt. 4, Houston, Tex.
Winkler, B. O. (Geophysicist, Socony-Vacuum Oil Co.), 33 Greenview Way, Montclair, N. J.
*Winn, Clayton N. (Office Manager, Geoph. Dept., Amerada Petroleum Corp.), Box 2040, Tulsa 2, Okla.
Winnek, James R. (Drilling Supervisor, Amerada Petroleum Corp.), Box 2140, Tulsa 2, Okla.
Winter, A. B. (Division Radioactivity Engineer, Lane-Wells Co.), Box 1407, Houston, Tex.
Winter, Niles B. (District Geologist, Atlantic Refining Co), Box 871, Midland, Tex.
Winterhalter, A. (Research Engineer, Sun Oil Co.), 695 Pine St., Beaumont, Tex.
*Wise, Henry F. (Computer, United Geophysical Co.), Box 809, Seminole, Tex.
Wise, J. B. (Party Chief, Garrett Exploration Co.), 7015 Hillcrest Ave., Dallas, Tex.
*Wise, Richard A. (Field Crew Computer), c/o Socony-Vacuum Oil Co. of Ven., Apartado 246, Caracas, Venezuela, S. A.
Wolf, Alexander (Consultant), 4708 Caroline St., Houston 4, Tex.
Wolf, D. J. (Chief Geophysicist, Kerr-McGee Oil Indus., Inc.), 500 Kerr-McGee Bldg., Oklahoma City, Okla.
Wood, Arthur B. (Geophysicist), c/o Caribbean Petroleum Company, Apartado 809, Caracas, Venezuela, S. A.
*Woodard, D. H. (Eastern Supervisor, Miller Geophysical Co.), Allen Grove, Wisc.
Woodburn, J. E. (Supervisor, Seismograph Service, Ltd.), c/o Trinidad Leaseholds, Ltd., Pointe-a-Pierre, Trinidad, B. W. I.
Woodruff, C. R. (Gravity Party Chief), c/o Shell Oil Co., Inc., Box 720, Casper, Wyo.
Woods, J. P. (Geophysicist, Atlantic Refining Co.), 3629 Cragmont, Dallas, Tex.
†Woods, Melville Edgar (Lecturer in Physics, McMaster University), 147 Wentworth St. N., Hamilton, Ontario, Canada.
Woods, Robert E. (Geophysicist, General Petroleum Corp.), 1199 Calaveras St., Altadena, Calif.
Woodward, Richard H. (Research Fellow, Massachusetts Inst. of Tech.), 12 Wendell St., Cambridge, Mass.
Woolley, William C. (Seis. Computer, Magnolia Petroleum Corp.), Box 900, Dallas Tex.
Woolson, John R. (Seis. Party Chief, United Geophysical Co.), 822 Thompson Bldg., Tulsa 3, Okla.
Wright, Ray H. (Party Chief, Geophysical Service, Inc.), 1311 Republic Bank Bldg., Dallas 1, Tex.
†Wuenschel, Paul C. (Student, Columbia University), 433 East 25th St., Erie, Pa.
Wyckoff, Ralph D. (Chief, Geophysical Research & Development Div., Gulf Res. & Dev. Co.), Box 2038, Pittsburgh 30, Pa.

*Yates, Cal (Computer, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Yeates, F. L. (Party Chief, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.
Yokubaitis, A. C. (Party Chief, American Exploration Co.), 204 N. Chestnut St., Lafayette, La.

*Young, Wilbur H., Jr. (Chief Geologist), c/o Empire Gas & Fuel Co., Wellsville, N. Y.
*Yungul, Sulhi (Geophysicist), c/o M. T. A. Enstitusu, Ankara, Turkey.

Zavoico, Basil B. (Consulting Petroleum Geologist & Engineer), 220 East 42nd St., New York, N. Y.
*Zebal, George P. (Development Geologist), c/o California Co., 1006 U. S. National Bank Bldg., Denver, Colo.
Zenor, H. M. (Consulting Geophysicist), Box 2, Kittredge, Colo.
Zimerman, Sam (Chief Geophysicist), c/o Standard Oil Co. of Egypt S. A., 22 Sharia Kasr el Nil, Cairo, Egypt.
Zimmerman, C. C. (Manager, Keystone Exploration Co.), 4012 Inverness Dr., Houston 6, Tex.
Zirbel, N. N. (Supervisor, Independent Exploration Co.), 901 Esperson Bldg., Houston 2, Tex.

MEMBERSHIP LIST BY GEOGRAPHICAL LOCATIONS

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Loveland
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Joesting, Henry R.
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Friendship Station
Straley, H. W., III

FLORIDA

Coral Gables
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Miami
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St. Petersburg
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Tallahassee
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Winter Park
Kaiser, Geo. B.

ILLINOIS

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Cram, Ira H.

Manito
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Mt. Vernon
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Robinson
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Roodhouse
Dunaven, W. A.

Sidney
Everitt, James

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Lafayette
Serviss, Fred L.

KANSAS

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McDaniel, C. M., Jr.

Ft. Leavenworth
Nahas, J. N.

Kansas City
Jones, H. H.

Liberal
Kunkel, T. L.

Wichita
Mercier, Vincent J.

LOUISIANA

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Bloomer, P. A., Jr.
Halsey, Raymond E.
Martin, W. Obier
Penny, R. T.
Roy, Chalmer J.

Donaldsonville
Galaway, Roy Lee

Hammond
Courtney, E. A.

Houma
Johnson, Byron K.
Morrison, W. D.
Sturdevant, John M.

Kentwood
Curnutt, F. E.

Lafayette
Conley, H. R.
Guseman, L. F.
Warren, Paul R.
Williams, Chas. C.
Yokubaitis, A. C.

Lake Charles
Holekamp, O. G.
Hunkapillar, B. B.
Loring, Ralph C.
Ratliff, D. W.
Reichert, H. C.

Mansfield
Walling, F. Rex

Maplewood
McDougall, John E.
Van Cleave, R. F.

Monroe
Partain, E. S.
Morgan City
Russek, I. W.
New Orleans
Atwater, Gordon I.
Brown, L. I.
Corbin, L. P.
Courtney, C. J.
Creighton, Roger B.
Crider, Lewis C.
Dobrick, Edward G.
Harris, J. A.
Holmer, Ralph C.
Hoover, J. W.
Howe, Ralph H.
Hudson, Joe B.
Meitzen, J. B.
Nichols, E. Turnley
Northrop, Joseph W., III
Partridge, John F., Jr.
Robert, Kearny
Smith, Neal J.
Totten, Stanley W.
Treybig, B. H.
Waggoner, J. Woodrow
Webster, Felix H.
Wiley, W. B.
Opelousas
Shafer, Russell E.
Shreveport
Barret, Wm. M.
Blanchard, Charles H.,
Bryan, Carl L.
Buchner, Harry M.
Burroughs, B. B.
Caster, E. L.
Clark, William W.
Fischer, L. F.
Freeman, L. I.
Goebbel, L. A.
Howard G. C.
Keen, C. D.
Lea, W. T.
Lindsey, E. B.
McKee, James B.
Rosencrans, R. R.
Spencer, Leslie C.
Taylor, John E.
Tilleux, H. O.
Wagoner, George E.
Walker, J. E.
Walker, J. R.
Wells, W. M.
Wilson, R. M.
Sulphur
Elms, R. G.
Moore, James A.

MARYLAND

Baltimore
Scharon, Harry L.
Swartz, J. H.
Silver Spring
Erickson, Anton
Melton, Ben S.

MASSACHUSETTS

Brookline
Maxwell, E.
Cambridge
Bradford, Donald C.
Faul, Henry
Oliphant, Charles W.
Woodward, Richard H.
Everett
Haskell, Norman A.
Harvard
Leet, L. Don
Lincoln
Tripp, R. Maurice
West Newton
Morgan, Charles Gill
Weston
Linehan, Daniel, S.J.
Woods Hole
Hersey, J. B.

MICHIGAN

East Lansing
Nisle, Robert G.

MINNESOTA

Minneapolis
Armstrong, Lee C.
St. Paul
Wetzel, W. W.
Virginia
Kendall, John M.

MISSISSIPPI

Brookhaven
Todd, James H.
Gulfport
DiGiulio, F. J.
Shapard, C. A.
Hattiesburg
Harding, R. N.
McCain, Hugh, Jr.
Whitley, W. M.
Jackson
Gaby, Ewin D.
Hathaway, M. S.
Perry, W. B.
Phillips, Robert R.
Rozsa, Theodore
Laurel
Tomlinson, John B.
Lucedale
Hawthorne, W. W.
McComb
Rase, H. L.
Natchez
Ferguson, J. G.
Gulmon, G. W.
Marshall, H. D.
Strange, Booth B.
Strange, O. A.
Vicksburg
Perret, William R.
West Jackson
Freel, J. F.
Harvey, Castle J. C.
Wiggins
Waddell, V. H.

MISSOURI

House Springs
Novelly, Walter O.
Joplin
Latimer, M. W.
Kansas City
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Meador, Bernal M.
Rockport
Polson, Mrs. G. S.
St. Louis
Blum, Victor J., S.J.
Honnell, Pierre M.
Macelwane, J. B., S.J.
Robertson, Miss Florence
Stearn, Noel H.

MONTANA

Billings
Cady, Francis H.
Clark, R. C.
Cronin, Stewart
Miles City
Colvin, C. E.
Red Lodge
McGann, R. J.

NEBRASKA

Lincoln
Souther, J. B.
Eustis
Wahl, Carl Christian

NEVADA

Reno
Kenneth L. Cook

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Marlboro
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Montclair
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Morristown
Jansen, J. J. H.
Red Bank
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Albuquerque
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Ruidoso
Evjen, H. M.

NEW YORK

Amawalk
Kelly, Sherwin F.
Hempstead
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Ithaca
Baird, John
New York City
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Gibbon, H. A.
Hardy, W. W.
Holser, Wm. T.
Kaufmann, G. F.
Kogbétliantz, Ervand
Lynch, J. Joseph, S.J.
Milstein, Mark
Olson, W. S.
Pekeris, C. L.
Rieber, Frank
Sauvé, N. B.
Skeels, D. C.
Weichert, R. F., Jr.
Whiton, H. F.
Zavoico, Basil B.
Rochester
Tompkins, F. A.
Syracuse
Siegert, A. J. F.
Wellsville
Young, Wilbur H.

NORTH CAROLINA

Elizabeth City
Quinn, Richard F.
Raleigh
Miller, E. L., Jr.

NORTH DAKOTA

Bismarck
Renden, Hugo R.

OHIO

Cleveland
Birkenhauer, Henry J., S.J.
Walter, E. J.
Dayton
Koenig, Palmer E.
Fairfield
Nash, Cleve C.

OKLAHOMA

Anadarko
McNally, P. M.
Patterson, A. R.
Bartlesville
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Bondurant, J. E.
Bradley, R. M.
Brownlow, C. L.
Courtier, Wm. H.
Crenshaw, C. C.
Dissler, Ernest
Ericson, Harry B.
Hintze, A. J.
Johnson, E. W.
Miller, Vincent
Owen, H. J.
Piety, R. G.
Rice, Robert B.
Tilley, Aubra E.
Chickasha
Long, C. J.
Mace, H. G.
Stones, J. Eugene
Duncan
Jackson, Kenneth
El Reno
Glover, Robert H.
Enid
Clifton, R. L.
Smith, Warren H.
Fort Sill
Jackson, Robert W.
Marlowe
Ervin, Lynn D.
Norman
Schriever, William
Oklahoma City
Campbell, D. B., Jr.
Clayton, Neal
Jones, Leland W.
Kamitchis, James F.
McMullin, Elbert F.
Smith, C. B.
Smith, Francis E.
Trombla, L. B.
Wolff, D. J.
Olustee
Kelley, Clovis C.
Pawnee
Farmilo, A. W.
Ponca City
Athy, L. F.
Crawford, John M.
Haber, A. F.
Hughes, Roland F.
Jordan, C. K.
Mount, E. L.
Prescott, H. R.
Richards, L. J.
Searcy, Frank
Swan, Bird G.
Vorheis, Byron
Whitehead, L. E.
Prague
Klabzuba, Robert E.
Sapulpa
McCready, H. J.
Shawnee
Buck, R. D.
Lukens, John P.
Smith, D. F.
Sulphur
Meade, George N.
Tulsa
Anderson, John F.
Andrews, H. H.
Barthelmes, Albert J.
Baum, Robert
Becker, H. C.
Bevan, Thomas J.
Bills, Robert N.
Bishop, F. L.
Borman, Frank W.
Born, Wm. T.
Boucher, F. G.
Bowman, D. C.
Brown, Henry W.
Bryan, A. B.
Buffum, C. Emery
Bullock, Robert L.
Campbell, F. F.
Carter, R. W.
Chang, Tun Yin
Christie, Norman J.
Cline, A. F.
Coffin, R. Clare
Connell, Joe E.
Cooley, E. H.
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Friendly, Jack L.
Frost, Noel
Fruehling, S. W.
Garner, J. P.
Garpmer, E. U.
Gemmer, R. W.
Gibson, G. D.
Gilliam, J. T.
Gilmour, Andrew
Giltinan, G. M.
Green, W. G.
Grimm, G. A.
Hammett, John P.
Handley, E. J.
Harbach, Robert G.
Harlton, Bruce H.
Hartline, Ralph E.
Hawes, Julian K.
Hawkins, J. E.
Hays, Clyde L.
Hoffman, John C.
Hollis, Jack L.
Hopkins, James S.
Houghton, H. M.
House, A. Maxwell
Hurry, Clare N.
Hutchinson, C. C.
Innes, Arland I.
Jeffers, Paul H.
Jones, Huston T.
Jones, John Paul
Jones, V. L.
Kendall, G. D.
Kendall, W. B.
Kezeler, J. L.
Kittredge, F. R.
Kundert, Karl H.
Lambert, G. D.
Lambkin, Woodrow W.
Lang, Harold M.
Lash, Charles C.
Lawrence, K. M.
Laws, J. O.
Leedy, F. B.
Ludwick, C. C.
Lynn, Ralph D.
Lyons, Paul L.
Manhart, T. A.
Martens, W. P.
Martin, Dick
Mayes, Tom D.
McAlister, C. H.
McClure, C. E.
McCollum, E. V.
McNatt, E. M.
Mehringer, A. P.
Mitcham, Frank M., Jr.
Moore, Homer C.
Moore, W. Lee
Mossman, R. W.
Nash, Jno. M.
Neufeld, J.
Officer, Helenita V.
Page, C. Newton
Pakiser, Louis C.
Palmer, John E.
Peery, W. R.
Pentecost, Claude D.
Pugh, William E.
Raborn, Smiley, Jr.
Rankin, C. T.
Reed, David E.
Reed, George W.
Reid, A. C.
Rich, J. M.
Richardson, J. W.
Rickel, Wesley K.
Ricker, Norman
Riess, Malcolm
Roark, James J.
Robertson, K. A.
Rollins, J. C.
Romberg, Marvin
Ross, C. M.
Ross, John W.
Ross, R. B.
Rupnik, John J.
Rutledge, Richard B.
Seaman, L. O.
Scott, C. B.
Sharpe, Joseph A.
Silverman, Daniel
Smith, Frank B.
Southgate, Tom F.
Sparks, Neil R.
Spearing, Edwin W.
Stotler, Thomas C.
Stover, Edward B.
Strachan, Clyde G.
Sype, William R.
Swearingen, A. C.
Taylor, Albert
Taylor, Garvin L.
Thomas, T. J.
Thralls, H. M.
Tucker, R. H.
Von Croy, Stefan
Vernon, Jess
Waldrep, W. Day
Walling, Ray W.
Walton, James I.
Ward, Dwight E.
Weatherby, B. B.
Weingartner, R. A.
Westby, G. H.
Widess, M. B.
Wilcox, Stanley W.
Williams, P. S.
Wilson, James N.
Winn, Clayton N.
Winnek, J. R.
Woolson, John R.

OREGON

Mount Vernon
Culp, H. A.

PENNSYLVANIA

Bethlehem
Agocs, W. B.
Bradford
Barber, R. C.
Erie
Wuenschel, Paul C.
Lemoyne
Jones, J. Byron
New Kensington
Fink, Paul O.
Norwood
Bazzoni, Charles B.
Palmerton
McMurray, Howard V.
Philadelphia
Jensen, Homer
Pittsburgh
Affleck, James
Allon, Michael
Backman, John E.
Bailey, Lothrop H.
Barbour, P. C.
Bender, Fred A.
Butler, Mark D.
Cerveny, Philip F.
Cook, D. E.
Copeland, R. J.
DeWoody, D. A.
Diveley, Paul R.
Doolittle, Russell C.
Eckhardt, E. A.
Elkins, Thomas A.

Gardner, Louis W.
Gealy, Wendell, B.
Gunn, J. E.
Hammer, Sigmund I.
Hastings, W. K.
Herron, Robert C.
Jones, R. W.
Kerbow, R. B.
Kilborn, J. M.
Lamb, William C.
McCracken, Guy I.
Meszaros, W. A.
Muskat, Morris
Palmer, E. M.
O'Donnell, T. J.
Peters, L. J.
Reiser, Robert C.
Robinson, John L., Jr.
Robinson, W. Bernhard
Staples, Guy W.
Texter, John W.
Watson, George R.
Wert, Carl M.
Westrick, E. W.
Wickerham, M. D.
Wyckoff, R. D.

Ridley Park
Johnson, F. L.

State College
Bacon, Lloyall Orrin
Pirson, Sylvain

Verona
Muffly, Gary

SOUTH DAKOTA

Newell
Jennings, D. Mitchell

TENNESSEE

Oak Ridge
Garrett, George A.
Pickle, Chesley B.

TEXAS

Abilene
McFarland, E. R.
Miller, Nash H.
Olson, Odell C.

Aledo
MeLemore, Ethel Ward

Amarillo
Moody, N. K., Jr.
Notley, W. E.

Andrews
Bychok, Victor

Athens
Smitherman, Lynn A.

Austin
Brown, Leon D., Jr.
Horton, C. W.
Hughes, Darrell S.
Mims, Lewis
Romberg, Frederick E.

Beaumont
Carson, Roe W.
Conklin, Glenn M.
Ellis, L. G.
Hollingsworth, W. E.
Konz, Leo W.
McCormack, Harold R.
Millington, John W.
Siegel, Frank
Smiley, W. G.
Winterhalter, A.

Bellaire
Beeman, Keith R.
Buckner, Guy O.
Eby, A. N.

Big Lake
Burton, Raiford

Big Spring
Barnes, Chester F.

Birthright
Hargis, A. V.

Breckenridge
Hammial, L. L.

Cisco
Reeves, James R.

Coleman
Cheney, M. G.

Cooper
Noble, Francis H.

Corpus Christi
Howerton, Bert P.
McGuckin, Glenn M.
Weatherby, S. P.

Crain
Epperson, R. S.

Dallas
Adams, H. R.
Adams, Myron D.
Agnich, Fred J.
Alcock, E. D.
Arnett, R. D.
Arnold, Kingsland
Augustat, George
Autrey, D. W.
Ayres, J. Otis
Babb, John J.
Baird, Walter D.
Batson, James B.
Beers, Roland F.
Bonebrake, Walter C.
Bowler, Gordon E.
Breedlove, Ruth
Brown, H. Hallock
Browning, K. A.
Burg, Kenneth E.
Butt, Harding
Campbell, E. L.
Carter, Ray K.
Calhoun, F. F.
Cathey, John A.
Clewell, Dayton H.
Clifford, O. C., Jr.
Cobb, Howard L.
Coit, R. B.
Collingwood, D. M.
Cortes, H. C.
Crump, Oscar M.
Dahm, C. G.
Davidson, George B.
DeGolyer, E. L.
Dobyns, D. R.
Donnally, Chester J.
Douglas, Norvel
Dugan, Albert F.
Edmonston, William J.
Eichelberger, A. M., Jr.
Farrow, B. D.
Fetzer, E. L.
Fisk, Frank K.
Gaither, Jerrel
Garrett, M. M.
Gillin, Jno. A.
Godell, John J.
Granberry, H. E.
Graves, Earl
Green, Cecil H.
Gsell, R. N.
Haggarty, Patrick E.
Hamm, W. Dow
Hardin, Neal H.
Harkness, T. O.
Hathaway, W. W.
Henderson, J. B. H.
Henderson, Ross
Hieatt, Herbert F.
Hightower, C. H.
Hilger, C. L.
Hogg, W. B.
Holbert, Murrell
Horn, J. W.
Jarrett, Harry
Jennings, Bruce M.
Jones, M. P.
Jonsson, J. E.
Karcher, J. C.
Kelsey, Martin C.
Kennedy, Edward P.
Kennedy, Frank H.
Kern, Jack C., Jr.
Kiesler, Ernest A.
Kohler, G. J.
Lester, John A.
Livingston, E. C.
MacNaughton, L. W.
McBurney, Charles G.
McCain, Hugh, Jr.
McCarver, Holland C.

McDermott, Eugene
McKay, A. E.
McLoad, Kenneth W.
Menefee, James C.
Minton, J. P.
Mitchell, W. R.
Moody, Herbert
Moore, C. M.
Moore, F. A.
Moran, Ray O.
Myers, John R.
Nash, Paul E.
Newton, W. W.
Nugent, Roderick M.
Oden, A. J.
Olson, R. W.
Pasley, L. C.
Payne, J. E.
Pellillo, M. J.
Pernell, J. H.
Perryman, J. D.
Peters, Jack W.
Pittman, C. V. A.
Porter, C. P.
Ransone, W. R.
Raper, W. B.
Reagor, Edward C.
Reeves, J. R.
Renner, Darwin S.
Robinson, George W.
Rose, H. W.
Seifert, Wesley H.
Seiler, Geo. E.
Shepherd, Cuth K.
Shugart, T. R.
Smith, Randolph
Smithwick, H. B.
Spangler, H.
Steel, D. M.
Stehr, Raymond A.
Storm, Alfred E.
Stulken, E. J.
Terry, R. D.
Teufel, Virgil W.
Thompson, R. P.
Tottenham, W. M.
Valkus, James W.
Waller, J. A., Jr.
Walsh, T. N.
Waters, Kenneth H.
Williams, Floyd J.
Wilson, E. E.
Woods, J. P.
Wobley, William C.
Wright, Ray H.

Ft. Worth

Balbin, Paul D.
Dana, R. H.
Davis, Rollin E.
Dudley, Raymond W.
Harris, Sidon
Hollingsworth, W. Wise
Hunzicker, A. A.
Itten, Howard
Johnson, James F.
Kerr, V. Robert
Lang, Ralph H.
Ledyard, Paul H.
Lovejoy, J. B.
Morehead, Jack N.
Morris, James L.
Normand, S. R.
Peabody, Miss Gwendolyn
Sanders, C. W.
Schouten, F. H.
Suggs, M. L.
Thomsen, Erik
Van Steenbergh, S. K.
Warren, Kirby J.
Wilson, John H.

Garland

Conover, George E.
Stanton, Austin M.
White, R. H.

Grapevine

Deacon, L. E.

Hamilton

Stiles, Miss E.

Houston

Aderman, C. V.
Adler, Joseph L.
Anderson, O. W.
Arthur, M. A.
Bader, Glenn E.
Banta, H. E.
Banta, N. H.
Barnette, L. Atmar M.
Beeth, Donald
Benke, M. L.
Bennett, Roy F.
Berg, G. A.
Berndes, A. E., Jr.
Bertram, A. C.
Bible, John L.
Black, J. P.
Blau, L. W.
Blight, Richard E.
Bolinger, John W.
Bowsky, M. C.
Boyd, Lewis H.
Briard, Vernon E.
Brooks, James A.
Broussard, C. H.
Broussard, D. F.
Brown, Andrew
Brown, Donald R.
Brown, Hart
Bruyere, R. N.
Bugbee, J. M.
Bunsen, A. W.
Burnett, A. C.
Butler, W. W.
Byers, John W.
Carlton, Dave P.
Carr, G. W.
Cash, Harvey, Jr.
Charrin, P. J. D.
Charske, Charles J.
Clark, George B.
Cole, R. C.
Cook, Paul C.
Cowles, Lawrence G.
Crary, Donald
Crowell, J. H.
Culbertson, J. A.
Dausman, R. H.
Davis, Donald M.
Deussen, Alexander
Dodd, Lavon C.
Doll, Henri Georges
Dunaway, J. H.
Dunlap, A. D.
Duty, Robert S., Jr.
Eberts, A. G.
Eby, J. Bryan
Falkenhagen, H. M.
Feagin, Frank J.
Ferguson, J. B.
Ferguson, Joe L.
Flude, J. W.
Fohs, F. Julius
Frosch, A.
Frowe, Eugene
Futral, John E.
Gardner, Derry H.
Gemmill, Edward J.
Geyer, Richard A.
Giezendanner, S. S.
Gilmore, John A.
Goldstone, Frank
Goss, Henry V.
Grange, Donald C.
Gregory, Carter H.
Griffin, I. M., Jr.
Guyod, H.
Hafner, W.
Hall, T. O.
Hamil, A. B.
Hamilton, W. Brooke
Hamm, J. G.
Happel, Henry H.
Harkins, Curtis P.
Harkins, T. I.
Harris, John
Harris, Phil C.
Haynes, C. J.
Heintz, Karl O.
Henderson, Bill
Henderson, M. R.

Henquet, R.
Herzenberg, A. J.
Hibbler, A. J.
Hibbler, M. E.
Hill, E. Bruce
Hinson, C. C.
Hoard, J. O.
Horvitz, Leo
Hovey, Ivan C.
Howell, Lynn G.
Hubbard, Charles L.
Hubbert, M. King
Hubby, L. M.
Hull, J. W.
Ivy, John S.
Jackson, R. S.
Jett, J. E.
Johnson, Frank B.
Judson, Sidney A.
Kannenstine, F. M.
Konkel, Philip M.
Krause, Fred W.
Ladner, A. L.
Lamb, George B.
LaRue, James E.
Lawhorn, O. T.
Lay, Roy L.
LeGrand, J. C.
Leonardon, E. G.
Leverich, Priestley
Lowe, C. R.
MacMahon, A. M.
Manes, O. B.
Marr, J. D.
Martin, Jack
Martyn, Phil F.
Martin, Sidney A., Jr.
Matthews, W. A.
McCann, K. G.
McCollum, Burton
McCullagh, John, Jr.
McDonnold, H. W.
McGee, John E.
McReynolds, Gregg F.
Miller, Robert D.
Millet, M. J.
Mitchell, George D., Jr.
Montgomery, G. P., Jr
Morrison, W. D.
Moose, Dale H.
Mott-Smith, L. M.
Mounce, W. D.
Mower, L. K.
Neff, W. D.
Nettleton, L. L.
Newby, C. J.
Norris, C. G.
Nutt, W. T.
Osterhoudt, W. J.
Oudt, F. W.
Palmer, R. L.
Parker, L. A.
Parker, Richard H.
Patrick, H. G.
Pawley, Julian K.
Peacock, H. B.
Petre, H. D.
Pollard, J. C.
Pranglin, John A.
Raines, Eli
Randolph, J. R.
Ray, Robert H.
Reed, Paul C.
Reynolds, F. F.
Riley, James K., Jr.
Robinson, Edwin H.
Rolshausen, F. W.
Roos, Lewis V.
Rossaire, E. E.
Rumsey, Paul T.
Rusch, Peter, J.
Ruska, Walter
Rust, W. M., Jr.
Sappington, Chester
Sargent, R. L.
Sauls, James L., Jr.
Saville, W. G.
Schaffer, Hugh C.
Schafer, Sidney
Schmidt, Henry
Schmuck, R. H.
Schofield, G. A.
Scholl, Louis, A., Jr.
Schumacher, J. P.
Selig, A. L.
Sharp, C. Sheldon
Sherer, E. A.
Sherar, Stuart
Shimek, E. J.
Shore, Harold F.
Sims, Sam E.
Slotnick, M. M.
Smith, A. L.
Smith, J. Angelo
Smith, Noyes D.
Somers, George B.
Starr, A. G.
Steele, W. E. Jr.
Stewart, S. B.
Stone, George B.
Stratton, Everett F.
Strong, J. Randolph, Jr.
Swartz, Charles A.
Sweet, R. C.
Taylor, W. Harlan
Terry, Melvin C.
Thompson, R. R.
Tucker, Robert L.
Uhrig, Leonard F.
Van Melle, F. A.
Unger, Earle E.
Urban, L. M.
Wallace, C. R.
Walton, Britain W.
Watt, J. S.
Weatherburn, K. R.
Weaver, Paul
White, S. A.
Whitsitt, C. D.
Wilber, Roscoe C.
Williams, E. D.
Williamson, Lonnie C.
Wingett, R. O.
Winter, A. B.
Wold, Alexander
Yates, Miss Cal
Yeates, F. L.
Zimmerman, C. C.
Zirbel, N. N.

Jacksboro
Owings, B. F.

Kingsville
Porter, Hugh

Lamesa
Forward, Fred

Levelland
Foote, W. L.
Kelsch, Raymond L.

Liberty
Lee, W. B.

Livingston
George, Fred Wm.

Longview
England, C. M.
Lohse, John M.

Lubbock
Conant, E. E.
Feather, V. G.
Heard, James R.
Houston, Chas. E.
Klaus, Hellmut
Morrison, M. S.

Madisonville
Musgrave, Albert W.

Marshall
Lea, N. J.

Maypearl
Thomas, E.

McAllen
Harris, B. A.
Russell, Dallas L.

Midland
Arick, M. B.
Bradley, H. W.
Dennis, Terrance E.
Doll, W. R.
Durham, Charles A.
Gibson, M. O.
Jasper, Walter E.
McKinsey, M. H.

St. Clair, D. W.
Shell, H. E.
Sklar, Maurice
Winter, Niles B.

Miller Grove
Gore, Robert F.

Odessa
Jackson, O. B.

Ozona
Head, E. I.
Scott, D. L.

Palacios
Sisson, H. H.

Palestine
Ingle, G. W.
Williams, Richard

Pampa
Gallie, J. F.

Pecos
Ruhlen, W. W.

Rankin
Harkey, W. J.

Riverside
Weinzierl, J. F.

Rosenberg
Myers, Charles E.
Neese, U. E.

San Angelo
Moore, Arthur A., Jr.
Shock, Lorenz I.

San Antonio
Allen, Thomas L.
Barbisch, J. B.
Bazhaw, W. O.
Bennett, Elwin
Crawford, Paul D.
Crawford, W. L.
Davis, L. A.
Dawson, Herbert M.
Donnelly, V. T.
Greenlee, Paul
Giles, Ernest Palmer
Hemmi, C. W.
Homan, W. L.
Imle, John F.
Kelley, W. W.
Kohler, A.
De Loach, E. L.
Narvarte, P. E.
Parr, J. D., Jr.
Petty, Dabney E.
Petty, O. S.
Petty, Van A., Jr.
Roberts, Homer E.
Roberts, Louin W.
Rudolph, P. J.
Schmidt, K. H.
Snow, Leland
West, Thomas S.
Wilkinson, A. L.

San Benito
Dunbar, R. O.

Sequin
Short, Walter E.

Seminole
Wise, H. F.

Sherman
Schiflett, H. L.

Sinton
LaRue, W. W.

Sonora
Thomas, J. W., Jr.

Texarkena
Farren, Paul

Three Rivers
Dexter, Lawrence N.

Tyler
Albertson, Miss Dorothy E.
Tefft, Gerald H.

Vernon
Bradley, Joe R.
Mills, Frank

Victoria
Sorrels, B. J.

Waxahachie
Schackelford, Lewis L., Jr.

Wharton
Jackson, G. L.

Wichita Falls
Crain, Robert A.
Mayfield, W. I.

UTAH

Salt Lake City
Marquardt, Carlton M.

VIRGINIA

Alexandria
Lipson, Edward
Mitchell, Fielding L.

Arlington
Fain, Edgar A.

WASHINGTON

Geiger Field
Hannum, Robert C.

Seattle
Etherington, T. J.

WISCONSIN

Allen Grove
Woodard, Dan H.

Madison
Slichter, Louis B.

WYOMING

Casper
Burton, Gerald A.
Dehlinger, Peter
Fenwick, Willis H.
Hohag, Walton H., Jr.
Hughson, B. B.
Larson, Carl L., Jr.
McGrady, H. D.
Thomsen, Harry L.
Tucker, M. D.
Winfrey, D. B.
Woodruff, Charles R.

Cody
Gilkison, Don

Kemmerer
Schombel, L. F.

Lusk
Stafford, C. J.

Rawlins
Johnston, Frank M.

ALASKA

College
West, S. Stewart

Fairbanks
Legge, J. A. Jr.
Rugg, Allen M. Jr.

FOREIGN

BELGIUM

Brussels
Evrard, Pierre

BRITISH WEST INDIES

Nassau, Bahamas
Heggblom, J. C.

Trinidad
Higgins, G. E.
Woodburn, James E.
Richards, T. C.
Watson, Robert J.
Wilkinson, Robert P.

CANADA

Alberta

Calgary
Armstrong, John A.
Chapman, C. J.
Chesher, C. E.

Farmilo, A. W.
Gallaway, John O.
Junger, Arne
Lockwood, R. P.
Paterson, R. G.

Edmonton
Roberts, Francis A.

Red Deer
Blundun, George J.

New Brunswick

Moncton
Hole, H. W.

Ontario

Hamilton
Woods, M. E.

Manilla
Rabey, W. N.

Owen Sound
Morley, L. W.

St. Catherines
MacSween, Geo. B.

Schumacher
Johnson, Albert E.

Sudbury
Selmser, Calbert B.

Toronto
Beck, August F.
Blanchard, J. E.
Brant, A. A.
Collett, L. S.
Godefroy, Constant
Hodgson, John H.
Johnson, G. R.
Lundberg, Hans
MacNeill, W. J.
Randell, John T., Jr.
Sproule, J. C.

Quebec

Bourlamaque
Brown, F. W.

Val d'Or
Koulomzine, T.

CUBA

Havana
Morgan, Wesley H.
Tucker, Paul M.

DENMARK

Kobenhaven
Reitzels, C. A.

EGYPT

Cairo
Blakey, Carl W.
Barkouky, Ahmed Nasr
Carr, John
Cornett, J. R.
Frost, H. H.
Jubran, Joseph
Schwennesen, A. T.
Seager, O. A.
Sibley, W. B.
Zimmerman, Sam

ENGLAND

London
Davies, Richard
Fitch, A. A.
Shaw, Herman
Tarrant, L. H.
Templeton, James C.
Van Der Linden, E. J. P.

Newark, Nottinghamshire
Germain-Jones, D. T.

Southwell, Nottinghamshire
Hales, F. W.

FRANCE

Paris
Migaux, Leon
Schlumberger, Marcel

GERMANY

British Zone

Harburg
Stubbe, Gerhard

HOLLAND

The Hague
Baars, Bastiaan
Brons, H. H.
Ulrich, Victor P.
Van Weelden, A.

INDIA

Calcutta
Mehta, A. K.

Iraq
Finley, R. K.

MEXICO

Mexico City
Alvarez, Manuel, Jr.
Rojas, A. Garcia
Thomas, J. W.

Orizala, Vericruz
Moore, R. R.

Tampico, Tamps
Aldridge, R. F.

PALESTINE

Haifa
Grizzell, Edward I.

SCOTLAND

Meadowview, Leuchers Fife
Rait, David A.

SOUTH AFRICA

Johannesburg
Maree, Burgert D.
Weiss, Oscar

Pretoria
Enslin, J. F.

Springbok, Namaqualand
Malamphy, Mark C.

SOUTH AMERICA

Argentina

Buenos Aires
Martin, Rodolfo
Rey, Pedro
Roslosnik, Andres

Rosario
Castellanos, Alfredo

Rioja Province

Chilecito
Ramaccioni, D.

Brazil

Belem, Para
Linwell, Martin V.
Mann, Neil W.

Ponta Grossa, Parana
Guimaraes, Helio Pentagna

Rio de Janeiro
Denning, Wayne H.
Oddone, D. S.

Chile

Santiago
Grossling, Bernardo
Ramirez, John M.

Colombia

Barranquilla
Hart, M. M.
Lynch, Jack

Bogota
Bickel, Harold C.
Boots, Paul H.
Del Rio, Alejandro
Hazen, George H.
Hobbs, Theron E.
House, H. M.
Irby, W. L.
Itria, Oswald
Kidder, Harold J.
Klein-Haneveld, A.
Law, R. M.

Schauble, C. G.
Silva, Will
Smith, James A.
Stimler, Saul
Tallman, R. H.

Floresanto Camp
Hart, M. M.

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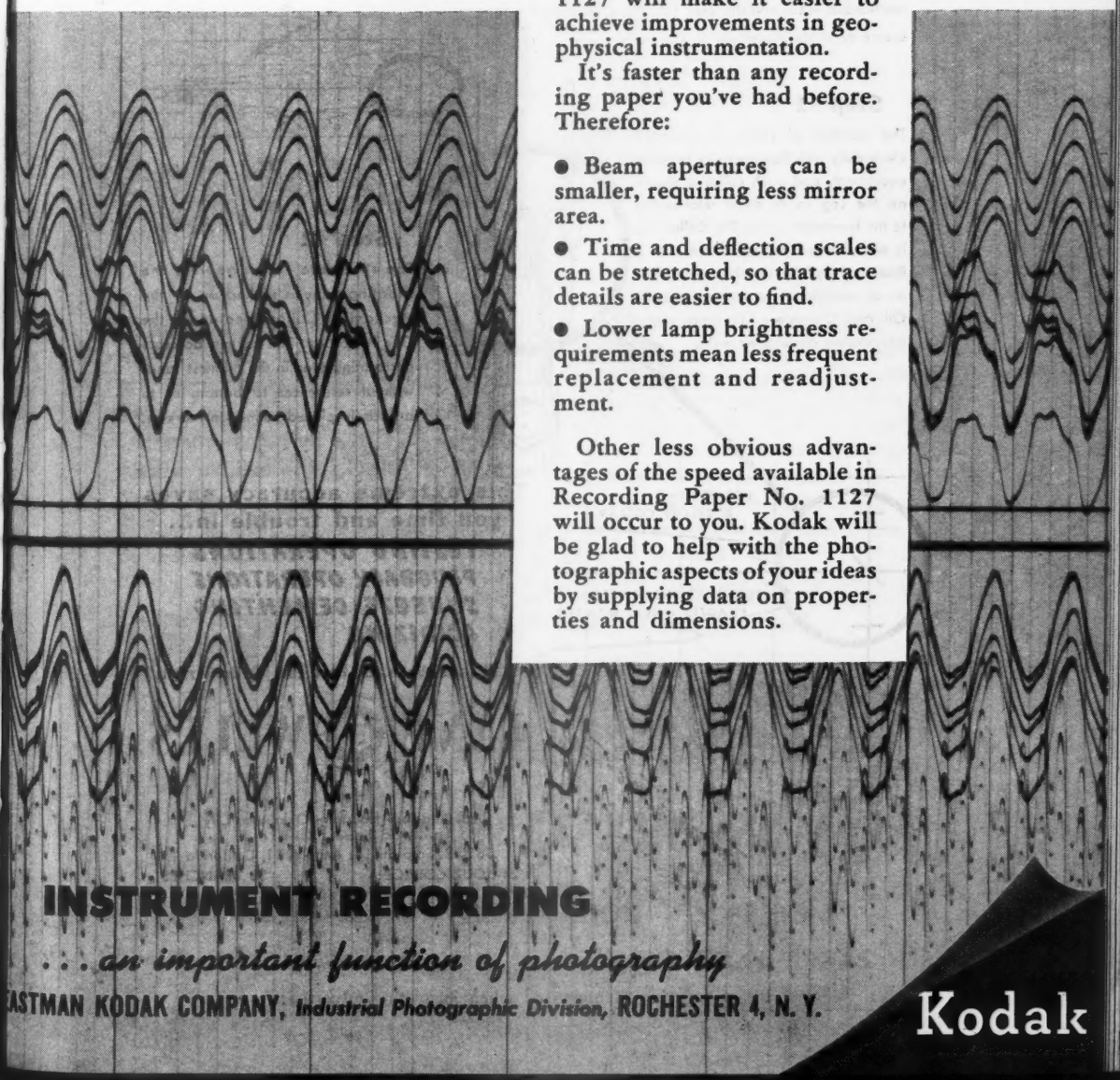

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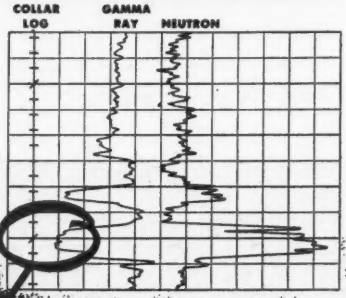

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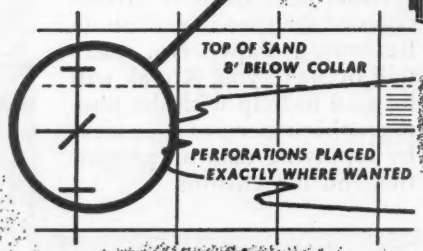

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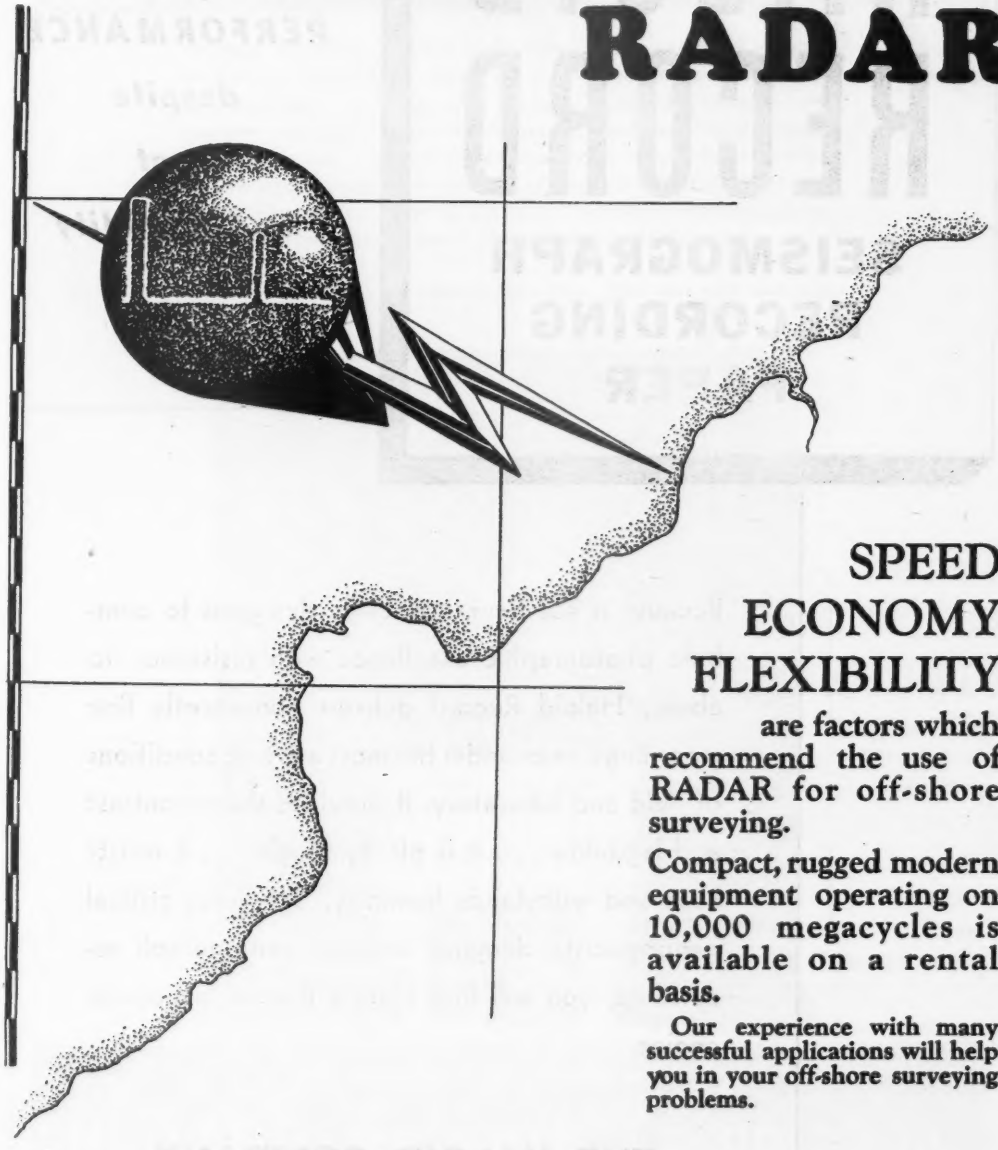

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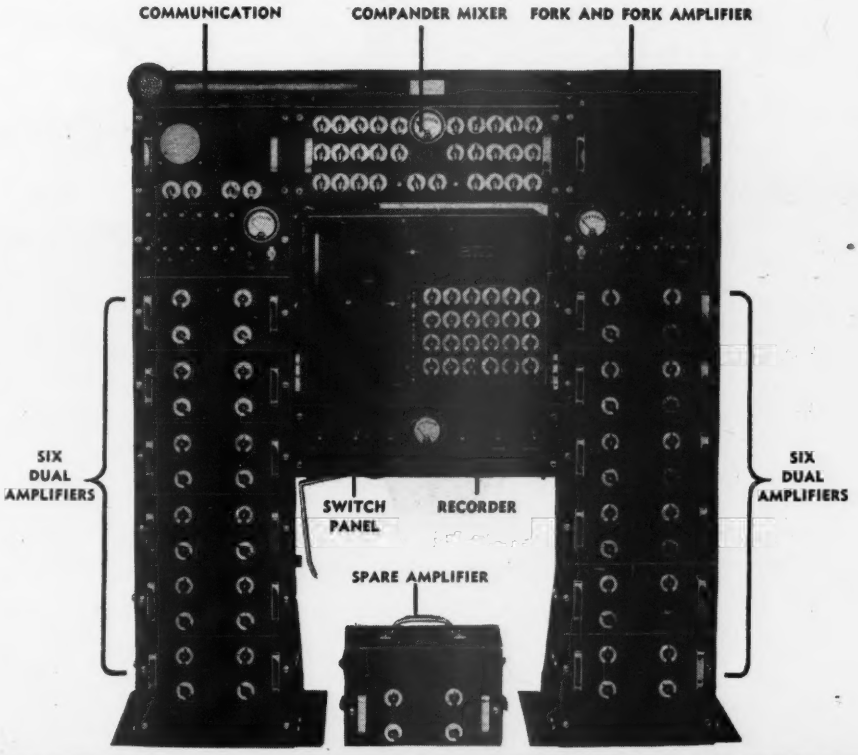

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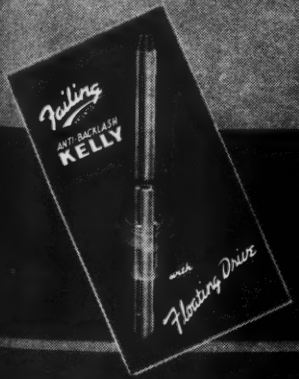

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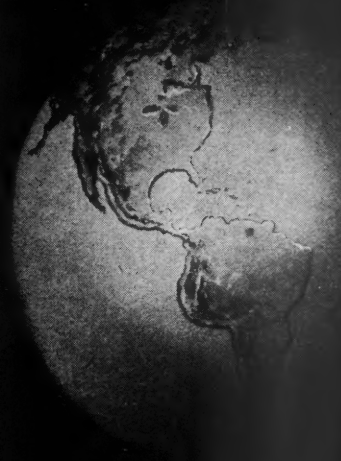

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EXPERIENCED AGGRESSIVE PERSONNEL

SINCERE FRIENDLY COOPERATION

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ADVANCED EXPLORATION COMPANY, INC.
622 FIRST NATIONAL BANK BUILDING
LABORATORY: 3732 WESTHEIMER
HOUSTON, TEXAS

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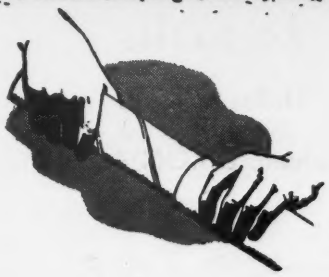
SPIRALOK

THE ORIGINAL DYNAMITE COUPLING FOR SEISMIC EXPLORATION

Easy to Assemble
Easy to Use

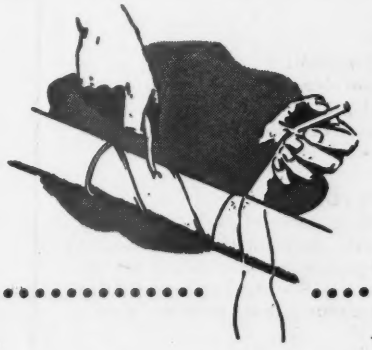


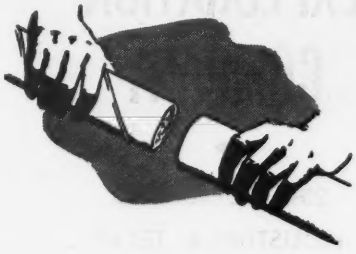
Quick, one-man assembly

Threaded Spiralok* cartridges and shells can be screwed together rapidly to form a long, rigid column of explosives.

Easy to prime

Insert cap anywhere in the cartridge before joining sleeves. Then screw sleeves together. Sleeves cover and protect cap, leave wires free.





Simple to take apart

Unneeded cartridges can be uncoupled rapidly by one man, without damage to charge or sleeve.

HERCULES POWDER COMPANY
INCORPORATED
917 King Street, Wilmington 99, Delaware

*Reg. U. S. Pat. Off. by Hercules Powder Company

measured at 1 MV

STANDARD PROCEDURE
for Thermador Geophysical Transformers

At Thermador there's nothing unusual about measuring a transformer at 1 MV. For *all* Thermador input, interstage and low-level transformers are measured at 1 MV and 100 MV. Furthermore, this information is placed on each transformer, assuring uniformity in any quantity ordered.

TOLERANCES HELD TO A REMARKABLE MINIMUM

Thermador transformers are held to a maximum tolerance of plus 5% to minus 5%. Special transformers with tolerances held from plus 3% to minus 3% are also available.

SPECIAL STAFF . . . EXCLUSIVE TESTING EQUIPMENT

A special geophysical staff and exclusive testing equipment assure the superiority of Thermador transformers. All inductance measurements are made with a specially designed Owens Bridge by applying certain measured voltages across the coil.

HERMETICALLY SEALED

Thermador Geophysical Transformers are hermetically sealed and vacuum impregnated to provide resistance against extreme conditions of humidity, heat and cold.

For complete information, write Dept. GT today.

"Seven Leagues Ahead"

THERMADOR
ELECTRICAL MANUFACTURING CO.
5119 District Boulevard • Los Angeles 22, California

THE
GEOTECHNICAL
CORPORATION

ROLAND F. BEERS
President

P.O. Box 7166
Dallas 9, Texas
Telephone DIXON 4-3947

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CORE DRILLING

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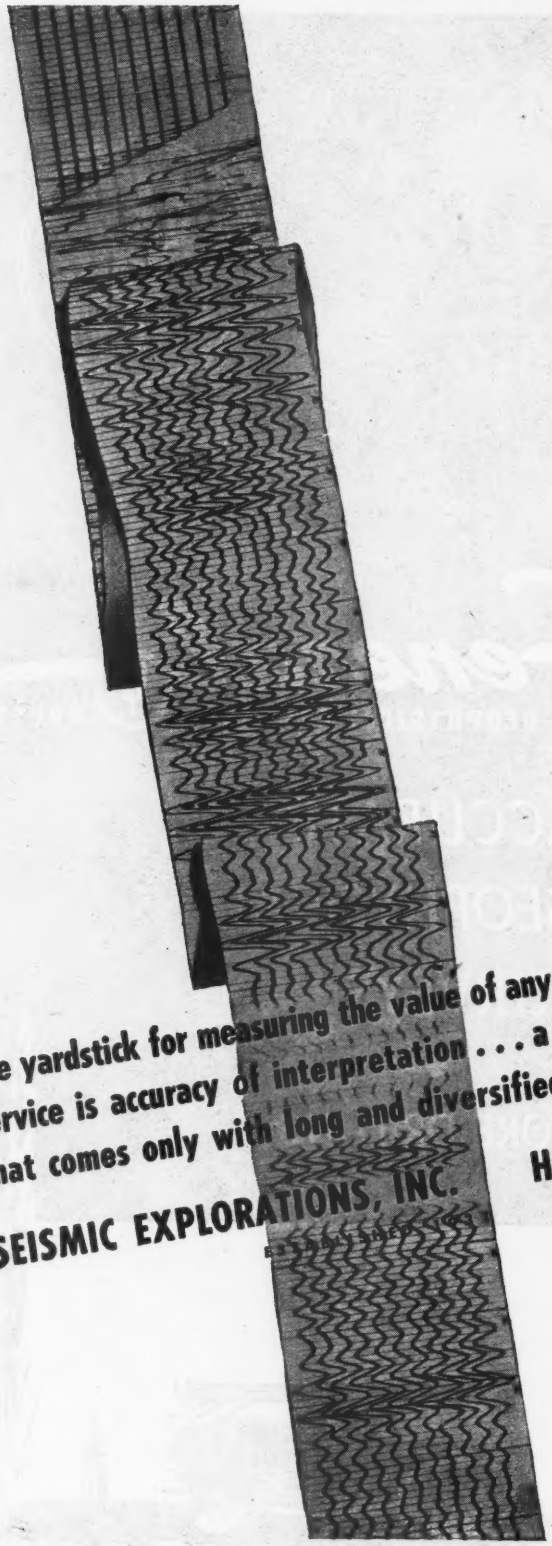

The yardstick for measuring the value of any seismograph service is accuracy of interpretation . . . a qualification that comes only with long and diversified experience.

SEISMIC EXPLORATIONS, INC. Houston, Texas

SOUTHERN

PRECISION SEISMIC SURVEYS

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SOUTHERN GEOPHYSICAL COMPANY

SIDON HARRIS, PRESIDENT

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SEISMOGRAPH INSTRUMENTS

by

SIE

- Amplifiers
- Oscillographs
- Radios
- Control Units
- Blasters
- Cable Break Locators
- Special Units
- Complete Unitized Recording Units
- Precision Transformers

Whether your need is for one of the above units or a complete Recording Truck ready to operate—Consult S. I. E. for instruments of proven design and dependability.

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Custom Built Geophysical Equipment

2619 Milam Houston 6, Texas

H. L. SCHIFLETT, MANAGER

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Service Interpretation

STATES EXPLORATION COMPANY

GRAVITY METER SURVEYS

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TO THE OWNERS:

Gentlemen:

From the beginning we have operated on the premise that your primary purpose in the conduct of geophysical surveys is to SAVE money or MAKE money;

YOU SAVE by

1. Not buying
2. Not holding

YOU MAKE by

1. Buying in the right place
2. Drilling in the right place

To this end our field surveys are carefully conducted and the interpretation of data made in close harmony with YOUR GEOLOGISTS.

HLS:hk

Very truly yours,

N. L. Schiflett

LIKE LOOKING FOR FAVORABLE FORMATIONS,

WITHOUT ADEQUATE GRAVIMETRIC METHODS!

Economy of usage — swiftness and sureness of assembling data — PRIMARY reasons why Gravity Meter Surveys come FIRST in scientific pre-drilling techniques!

Mayes-Bevan now offer their professional skill and experience along this line, for consultation with you on your problems.

MAYES-BEVAN GRAVITY METER SURVEYS M B COMPANY

KENNEDY BLDG. TULSA, OKLAHOMA

One trip to the well
PROVIDES ALL THESE SERVICES...
saves costly rig time!
ELECTRICAL WELL LOGGING
SIDEWALL CORING
DIRECTIONAL SURVEYS
DIPMETER SURVEYS
RADIO ACTIVE DEPTH MARKER
Call SCHLUMBERGER for YOUR next GUN PERFORATING job—too.
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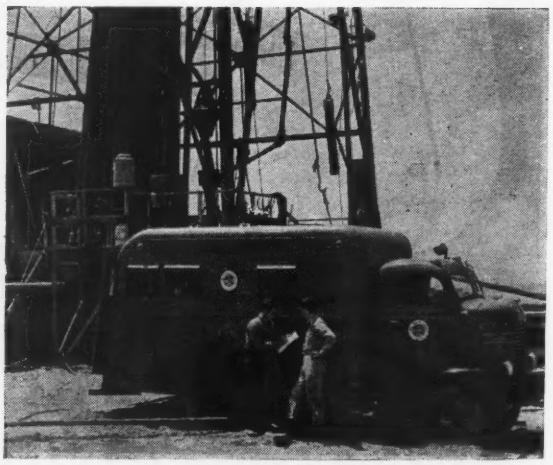
Integrated
WELL SERVICE
SCHLUMBERGER WELL SURVEYING CORPORATION • HOUSTON • TEXAS

Help insure your wildcat

- **WHY RISK the possibility of overlooking important producing horizons? Many new productive sands have been tested due to the results of Baroid Well Logging Service.**
- **KNOW YOUR WILDCAT! To obtain the most comprehensive data from your well, correlate the mud analysis log with the electric log and other well information.**
- **BAROID WELL LOGGING SERVICE supplies a continuous analysis of the returning drilling mud and does not interfere with drilling.**
- **Operators use it who desire immediate information on the occurrence of oil and gas as their wells are being drilled.**
- **Include BAROID WELL LOGGING SERVICE in your well program.**



FORMATION INFORMATION THRU MUD ANALYSIS

BAROID *Well Logging* **SERVICE**

Baroid Well Logging Units contain complete logging and mud testing equipment. Logging reveals the presence of oil and gas in the formations penetrated and practically eliminates the chance of passing any productive zones. By using this service to control a coring program, only the necessary cores need be taken, resulting in a great saving in time and money in drilling a well. Mud tests are made to maintain a satisfactory drilling mud.

BAROID SALES DIVISION

NATIONAL LEAD COMPANY ● BAROID SALES OFFICES: LOS ANGELES 12, TULSA 3, HOUSTON 7

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Presenting . . .

The Model SD-14
DC Vacuum Tube Voltmeter

Featuring:

- Special Weston meter with dual calibrated scale and lance pointer for easy reading.
- Moisture-Proof Case to meet conditions of high humidity.
- Sub-miniature tube, with extremely linear characteristics.
- Battery life of a year, under average conditions.

RANGE: 0.05 to 1000 volts in six ranges (3, 10, 30, 100, 300, and 1000 volts full scale).

ACCURACY: 2% for all ranges.

INPUT RESISTANCE: 100 Megohms on all ranges.

BATTERY LIFE: Over 500 hours.

WEIGHT: 4 pounds, including all batteries.

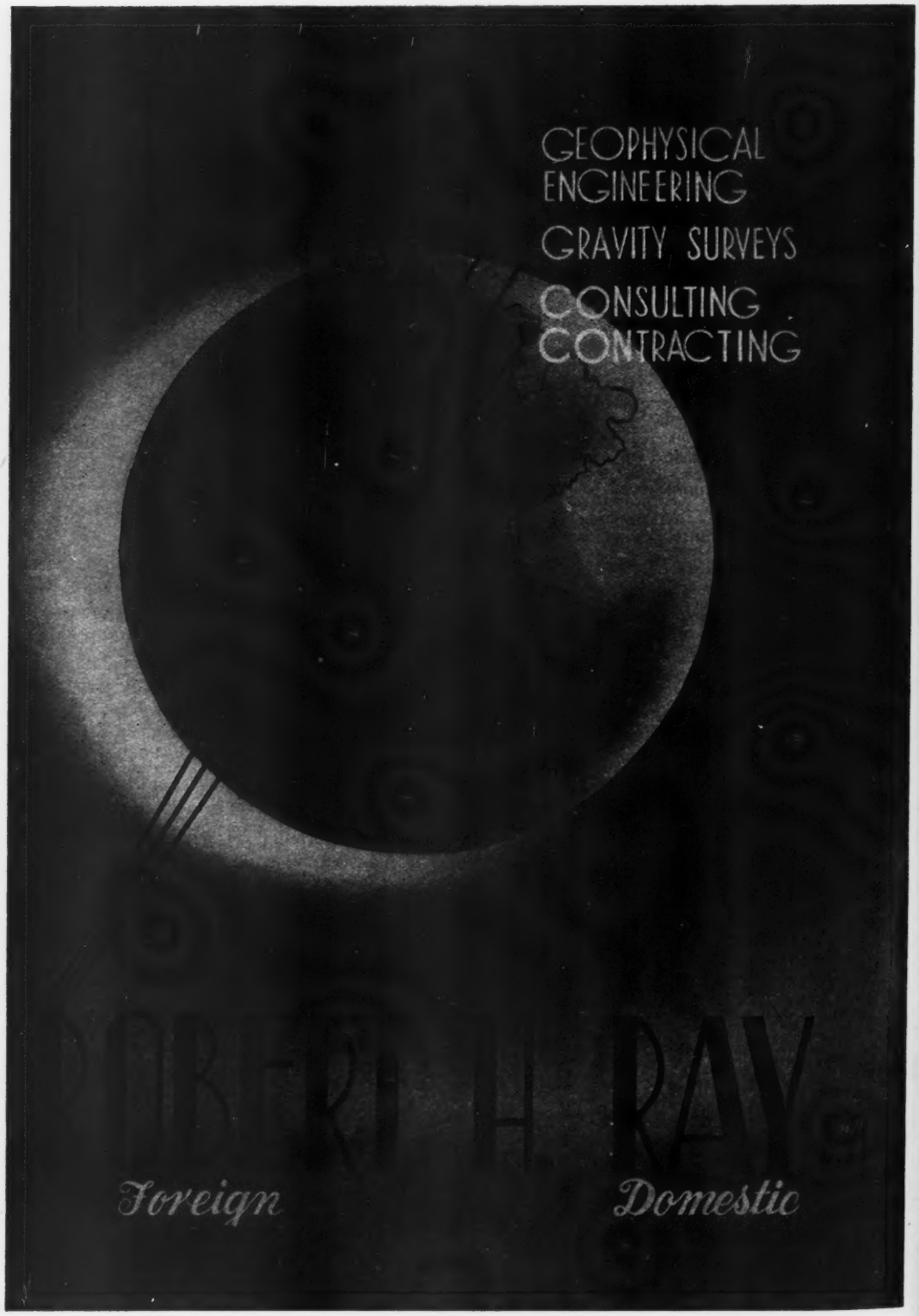
The entire instrument, including all batteries, is self-contained and housed in a black lucite case. The case has been moisture-proofed to insure accuracy and reliability under conditions of high humidity. The circuit components include 1% matched resistors, a precision meter, and a vacuum tube which has been designed for extremely linear grid voltage-plate current characteristics. These components, together with a circuit which practically eliminates all errors due to battery and tube aging, assures that specified accuracy is maintained over long periods of time.

This voltmeter was designed for accurate measurement of DC voltages on circuits where no appreciable amount of power can be taken from the circuit. It is particularly useful for measuring electrode voltages of vacuum tubes and cathode ray tubes in all types of electronic equipment and finds wide use in both laboratory and field applications.

Complete specifications on request

THE DEVELOPMENT ENGINEERING COMPANY

1818 ASHLAND STREET HOUSTON 8, TEXAS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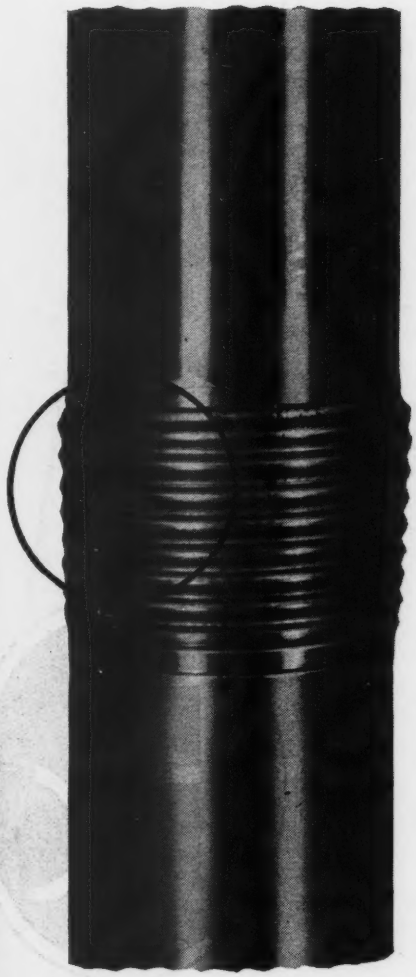
HOW THIS SHOT HOLE CASING SAVES MONEY THREE IMPORTANT WAYS



(1) Lighter Weight

Whether on land, marsh, or water, extra weight means extra trips. Textube is light (2 lbs. per ft.), gives you extra casing footage and lower hauling expenses.

(2) Quicker Makeup

3 revolutions make up this integrally rolled tapered thread connection. These tapered joints make stabbing easier and save running time.

(3) Higher Recovery

No cut threads to weaken the casing. Full casing thickness at all points on this tapered thread gives maximum strength for pull-out operations.

Uniform lengths

Textube casing is made in accurate uniform lengths for easy handling in swamp and foreign work. The uniform length also makes it easy to figure the number of joints required.

Widely used by majors and independent contractors

Thoroughly proved throughout domestic and foreign areas, Textube is ideally suited for any field of operation.

TEXAS STEEL AND TUBES COMPANY

1504 Oliver St. Phone Fairfax 0384
P. O. Box 7572 Houston 7, Texas
Cable address: "Textube" Houston

Tex-Tube PATS. PEND.

ELECTRIC WELDED STEEL

SHOT HOLE CASING

SPECIFICATIONS

3" O.D., 16 gauge resistance welded S.A.E. 1010 tubing is used. 8 tapered threads per end are integrally rolled into the tubing. ¾ inch taper per foot.

Distributed in Gulf Coast area by: Southern Sales & Transportation Co.

It's

INTERPRETATION

THAT *Counts* IN EXPLORATION

Modern science and inventive genius are reflected in today's precision equipment and advanced methods designed to determine geophysical data for oil exploration. But these methods and equipment are not enough. The producer of oil wants the most accurate and scientific analysis possible.

That's where INTERPRETATION comes in. Republic—founded and supervised by men who had an active part in the design and creation of some of these most modern methods and equipment—stresses the vital importance of ACCURATE INTERPRETATION. And, fortified by their wide experience in the direction of seismic surveys, Republic's geophysicists reach far beyond the normal limits of interpretive analysis.

Yes, Republic's clients have found that it's the INTERPRETATION that counts.

Rx

REPUBLIC EXPLORATION COMPANY

TULSA, OKLAHOMA

SEISMOGRAPH SERVICE CORPORATION
is proud to introduce a new subsidiary organization—

AMERICAN EXPLORATION CO.

of LAFAYETTE, LOUISIANA

The management of this new SSC subsidiary will remain unchanged; J. E. Lee, Jr., president; L. F. Guseman, vice-president and treasurer; and H. R. Conley, secretary; and its offices will stay in Lafayette, Louisiana.

The activities of American Exploration Company, for which it is particularly experienced and equipped, will continue to be marine seismic exploration. AEC crews are now conducting surveys off the Gulf Coast.

SSC's world wide experience acquired over many years and its extensive facilities will be employed to augment the specialized experience and facilities of American Exploration Company.

- ★ Seismograph Service Corporation of Deleware (South American)
- ★ Westby Geophysical Corporation (Mexico)
- ★ Seismograph Service Limited (Sterling Area)
- ★ Seismograph Service Corporation of Venezuela
- ★ Servicios Seismograficos de Colombia S.A. (Colombia)
- ★ American Exploration Company (U. S. A.)

Seismograph Service Corporation

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